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Admiral of the Fleet Sir GEORGE ROSE SARTORIUS, K.C.B., in the Chair.

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ON THE CAUSES OF THE INSUFFICIENT STABILITY OF H.M.'s LATE TURRET-SHIP "CAPTAIN," AND OF OTHER IRONCLADS.

By Rear-Admiral E. GARDINER FISHBOURNE, C.B.

I HAD retired from the consideration of subjects such as that which I am now to bring before you, until the loss of the "Captain," with her crew, forced on me the conviction that it was my duty to endeavour to prevent the recurrence of such.

Under these circumstances, and under the feeling that no time ought to be lost in bringing forward the subject, I must ask your indulgence if you discover undue haste and want of fulness in my treatment of the various questions involved. As to the insufficiency of illustration which must appear; I will let you into a secret—not to bind you to secrecy, but that you may give it extensive circulation; it is this, that information that belongs to the public cannot be obtained by public officers for public purposes, yet for some reason—scarcely patriotic—foreign Governments do obtain it without much difficulty.

Efforts have been made to show that the loss of the "Captain" was owing to her low freeboard; now this is not a private question that can be left in doubt. As there has also been an attempt to shift the responsibility of the loss upon Captain Coles, his memory demands an answer from one, who knew his public worth.

A comparison has been drawn between the "Captain" and the "Monarch," in proof of the danger of a low freeboard, and of the safety arising from a high freeboard. As to the first, I will deal with it hereafter; as to the second, I say to those who are responsible for the lives of the "Monarch's" crew, "if you would be clear, you must obtain better proof that she is safe, than that which has been given to the public."

The idea of increasing the topsides of a "Captain," with its accompanying heavy armour, thereby raising her centre of gravity, and reducing her already deficient initial stability, in reliance on the reserve of stability, developed by an indefinitely large angle of inclination, that might prevent her capsizing, needs no discussion; it carries with it its own condemnation. Those who know what a ship ought to be, know also, that ships are better for sailing on their bottoms than on their sides, and that if they are to be worth anything, they must possess stability enough to stand up while their guns are being pointed at the enemy, and not expose soft places under their armour for the enemy's shot.

To deny that a reserve of stability that shall preserve the essentials of a vessel of war can be given where it ought, as part of the initial stability in excess of the moments of sail, is to say, that though none of the Dutch vessels with their low freeboard in two hundred years, nor our own *no*-freeboard barges, have capsized, they ought to have done so, and that it was only their perversity that prevented it.

The existence of such establishes beyond reasonable controversy that Captain Coles' idea was one easy of achievement by an intelligent naval architect, if only he were furnished with the data which the Constructive Department of the Admiralty could supply—data which no private builder could possess, but which should be at the service of the public,—since Government exists for the country, not the country for Government;—how much more, then, when the data are required for State purposes.

The idea of a low freeboard arose with the "Nancy Dawson," which Captain Coles designed in the Black Sea, in the shape of a raft, for light draught; this vessel he found also gave him a steady platform for his guns, not simply that she possessed infinite stability, but because she was low in the water, and so the waves played freely over her platform.

It is clear, then, that the prominent ideas in his mind were,—great initial stability, and a lowness of freeboard that would allow the seas to pass over the deck rather than toss her up or over.

That the first idea was not realized, and the second only in part, was not his fault, as they belonged to the province of the Naval Architect, which he never professed to be; and in many of his drawings he omitted the ship's bottom, to mark that he did not hold himself responsible for that.

Had the "Captain" been endowed with a proper amount of initial stability, she would have been safe, and even the sea which precipitated the catastrophe would have broken harmlessly over her.

This could have been effected by lowering her centre of gravity (or not raising it from the place in the design), which it is admitted would have made her safer, but this, it is *erroneously* asserted, would have made her uneasy. Thus, a fancy was preferred to the assured safety of the crew, a judgment and reasoning not likely to raise our estimate of our constructors, nor to increase the confidence of the sailor in his ship, to whom this language conveys the idea of a short life but an easy one. How much longer are the lives of our men to be left at the mercy of such reasoners?

We have it on record that it was intended that her meta-centre should be 4 feet 6 inches above her centre of gravity; this was said to be as much as that in some good and safe ships, in which the distance was said to be overmuch.

The distance actually proved to be only 2·66 ft.

The height of the meta-centre above the centre of gravity is generally accepted as giving a near estimate of the relative statical stabilities of ships particularly if they are somewhat similar in character.

Taking this as the basis of our judgment, it may be seen what was the "Captain's" designed stability, as compared with known and fully tried ships, thus—height of meta-centre above centre of gravity:—

"Orion"	6·127
"Conqueror"	4·589
"Racoon"	5·390
"Cadmus"	4·860
Or "Perseverance," partly laden ..	3·6956

though this last ship had capsized *in dock*, and had to be brought to the above by 350 tons of ballast. If we compare the "Captain" with ironclads of known stability, we have—

"Prince Consort"	6·01
"Valiant"	4·61
"Warrior"	4·678
"Minotaur"	3·879
Or even "Bellerophon"	3·28
"Penelope"	3·50
"Captain" designed	4·57
"Captain" as built	2·66

Therefore instead of the "Captain" having less stability than the "Warrior," as the former had a low freeboard, she ought to have had *greater* initial-stability by the estimated amount of reserve-stability obtained by the high side of the "Warrior."

Yet this is considering the ship only in her holiday equipment, for when her coals, stores, provisions, &c., were out, her stability, as designed, would have been reduced to 3·17, in fact it was reduced to 1·29! Comparing that with the light draughts of known ships we have—

"Valiant"	.. .. ..	3·043
"Warrior"	.. .. ..	4·474
"Prince Consort"	.. ..	5·416
"Penelope"	.. .. ..	3·400
"Bellerophon"	.. .. ..	2·48
"Captain" (designed)	.. ..	3·17 about
"Captain" (actual)	.. ..	1·29

Till within a few years, the whole compass of the British Fleet did not present one case of a safe ship with so little stability as that of the "Captain."

As the Constructor of the Navy reported in 1866 that the "Captain" had been "*well designed and proportioned, and would not materially differ* "*from a ship that would have been prepared in their Department*, had their "Lordships seen fit to sanction in our design an upper *deck* 8 *feet above* "*the water*," there can be no doubt that he had considered the effect of the "Captain" having a low freeboard, and had pronounced that she would have sufficient stability; *nothwithstanding* also when he found that she was immersed 22 inches beyond her designed draft, and had thereby lost much stability, he must still have thought,—as may fairly be inferred from his taking no action to prevent her being received into the Navy,—that she had still sufficient stability, and this view is in entire harmony with the practice illustrated in the ships of the "Invincible" class and others, and with the argument contained in the work "Our Ironclads," wherein it is argued that a further reduction than that which had been made generally was desirable for the purpose of obtaining a steadier platform for the guns.

The "Captain" nevertheless was sanctioned and built and received into the Service as a safe ship, though she was immersed 27 inches more than was designed, and though 170 tons of the weight which tended to produce this result was placed many feet above the centre of gravity; still there was clearly no misgiving shewn, and the not complying with the request of Messrs. Laird to have her stability tested, after her armament had been supplied, was quite in harmony with this idea; further still, the officer who did test her stability stated at the Court-martial that he "saw nothing in it to cause us to apprehend, "in the face of "the report of the officer who had tried the ship at sea, that she was "in danger of capsizing." They had obtained, in their estimation, an exact measure of her stability, and they had no apprehension that she was deficient. How should they? They had been indoctrinated with the idea that stability was an encumbrance, as it was said by them to be a prime cause of a ship's rolling, and they had of late been giving ships of their own designing even less, thus the "Inconstant," the meta-centre of which was only 2·48 feet above the centre of gravity, with 91 tons of ballast; if this were removed it would shew the designed height of meta-centre to have been about 2·2, while that of the "Monarch" was only 2·38 feet as compared with the 4 feet 6 inches, or the actual 2·66 of the "Captain." The "Inconstant" heeled 15½° when the "Captain" heeled only 11°.

Under these circumstances it is obvious that the Officers of the Con-

structive Department of the Admiralty could not have thought the "Captain" unsafe. Nor, is this the whole evidence we have of their sentiments. Could they possibly have thought that the "Captain" was unsafe with a stability represented by 2·66, when they did not think the following ships unsafe, when lightened of coal, water, and provisions, so that their stabilities would be then represented by the following figures:—

"Monarch"	1·28 feet.
"Inconstant"	1·23 „
„ without 91 tons of ballast..	1·00 „
"Captain"	1·54 „

and though their stabilities are reported to be thus so very small, they are in fact even much less?

Now, however, that the result has proved that the "Captain" was deficient in stability, it is contended that this arose solely from the fact of her having had a low freeboard; that she possessed sufficient initial stability, but was deficient in that reserve of stability which it is alleged a high side necessarily gives, the reserve which is said, but untruly, to be the true security against capsizing.

After I had written the above, I learnt from the First Lord's Minute on the loss of the "Captain," that the conversion of the "Duncan" into a low freeboard turret ship was objected to by the Controller, and the then Constructor of the Navy, on the express ground that she would be in danger of capsizing, though she was to have had by their own showing an initial stability represented by

7·7 feet,

and by the projector's calculations,

9· feet.

Still they approve the "Captain's" design with

4·6 feet,

and accept her into the service with

2·66 feet.

This, however, is consistent with the idea that they had been acting on in their own designs, viz., that a vessel with great stability would, by consecutive waves, be rolled over if she encountered waves of her own period. This seems to us astounding enough. The ruling idea in it all—for I will not accept the alternative idea—is, raise the centre of gravity, get rid of stability, and avoid all designs in which it is projected to give much stability.

It is proper that I should remark on the "Captain" as designed as compared with the "Captain" as built.

In the design, the centre of gravity was intended to be about 3 feet below the load-water line at 23 feet draught, or 20 feet above the keel. She was, however, immersed to 25 feet, and the centre of gravity was about 3 feet from load water-line, or 22 feet above keel: that is, it was raised 2 feet above the place designed for it in the structure. This, allowing for the increase of weight, reduced her

statical stability one-third; that is, in round numbers, from 9,000 foot tons to 6,000 foot tons at 14° of inclination. Nor is this all. This increased depth of immersion below the centre of gravity of 2 feet increased the lateral resistance with a side wind, so that with half a mile an hour leeway, or 50 feet per minute, occasioned a tripping pressure at the keel tending to capsize her, equal to 1,200 horse-power.

And yet we have no intimation given of this danger, but instead, an outcry as to the loss of 2 feet in the height of freeboard!

The Constructive department of the Admiralty had learnt, at the public expense, that it was indispensable in building ironclads to put in short weight; they therefore ought to have given the Messrs. Laird notice of this, and further, have ordered their Superintending Officer to sanction a similar course in the construction of the "Captain,"—*not doing so, they ruined a fine ship.*

I think it will be clear to many that till experience had been swept out of the Constructive Department of the Admiralty, and true principles given to the winds, some of the ships mentioned, and others, would not have been built, nor the "Captain" have been accepted; for though Messrs. Laird designed her, the Officers of the Admiralty alone possessed the means of determining the actual quantity of initial stability that such an ironclad should possess. The responsibility for the loss of the "Captain" and that of her crew, must rest on those who did not furnish the information which success and the country required of its officers to give, the more incumbent on them because they had been strenuously inculcating the erroneous and dangerous doctrine that a ship was easy in proportion as her stability was deficient, so far misleading in the doctrine that proved fatal.

Stability is my theme, because stability is the life of a ship and more, it is death to the sailor, that a ship be without a sufficiency of this quality on the blue sea.

Stability, I repeat, for I must redeem the term from misappropriation, made on the plea of scientific terminalogy. The true use of the term is that to which we apply it, it is so also in science, for common sense and science are not yet divorced. Stability is the power of standing up *ab initio*, till disturbed or overthrown by a greater power, if only disturbed, it is the power exerted to return the body to the upright position more or less quickly as the quality is possessed in a greater or less degree. To be without stability is to be unstable, is to be indifferent to standing up, to be in danger of tumbling over, to be disturbed by the least force, and even to be upset.

"As stiff as a church" is a saying amongst sailors, but they do not mean that either one or the other is immovable, but only not easily moved. The hills have been rocked, but no one argues, therefore, that they were unstable, or without stability, neither is a ship truly said to be unstable because she rolls, or more unstable because she rolls more, nor may she be said to be stable necessarily because she does not roll, she may not roll much and yet be unstable, that was shewn in the case of the "Captain."

It would be desirable then to ascertain—

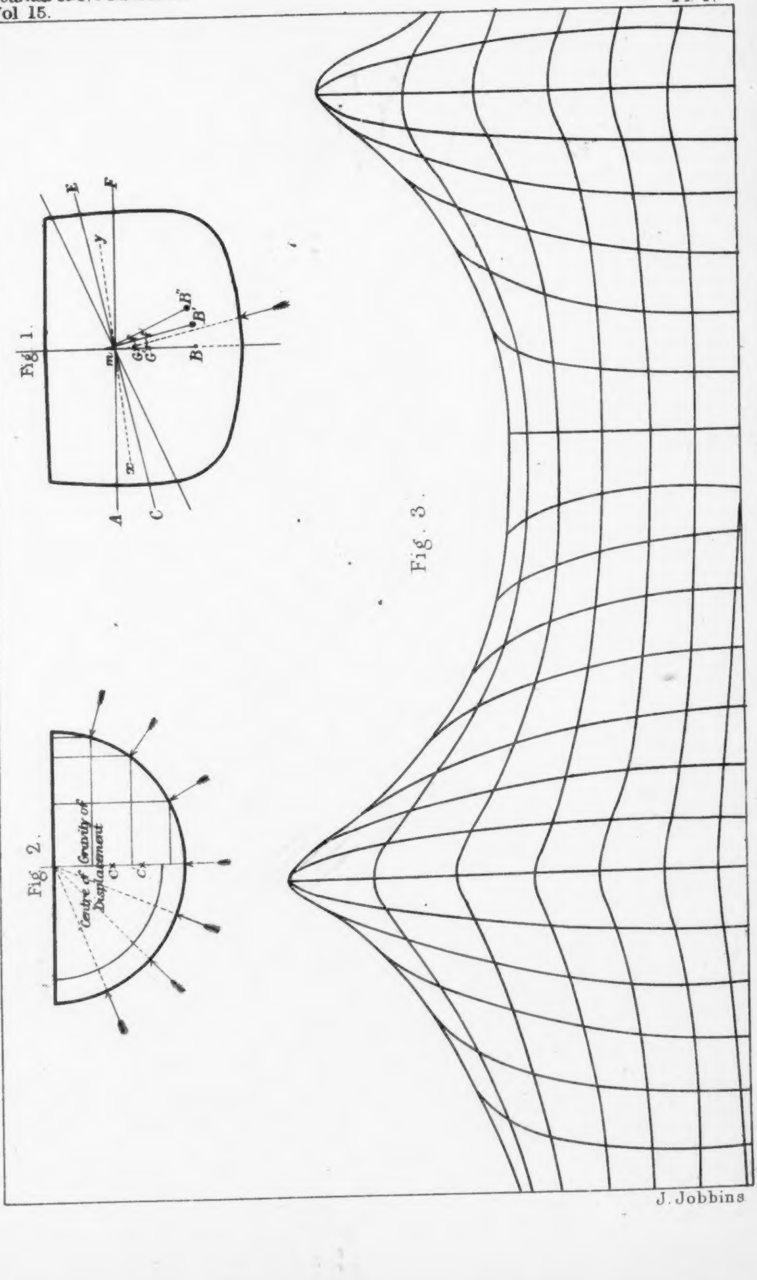
Fig. 1.
A
C
E
F
m
x
y
B
B'
B''
Fig. 2.
Centre of Gravity of Displacement
C
Fig. 3.

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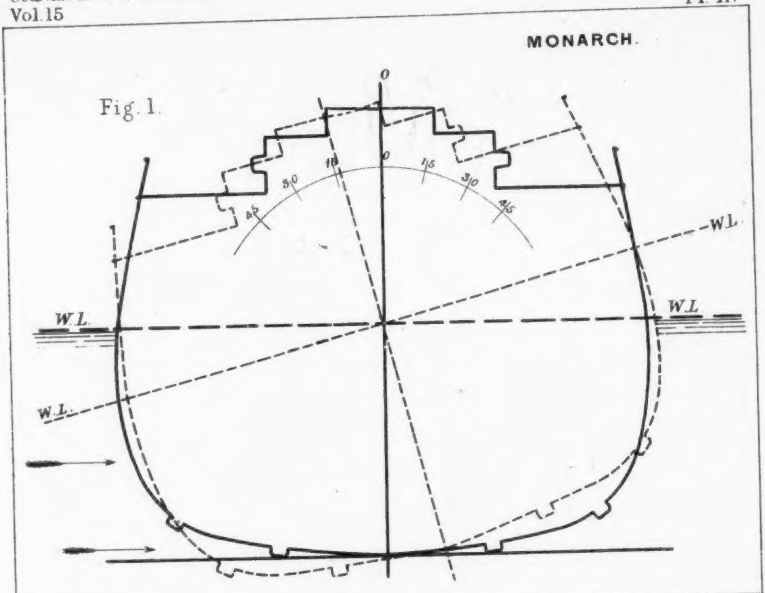
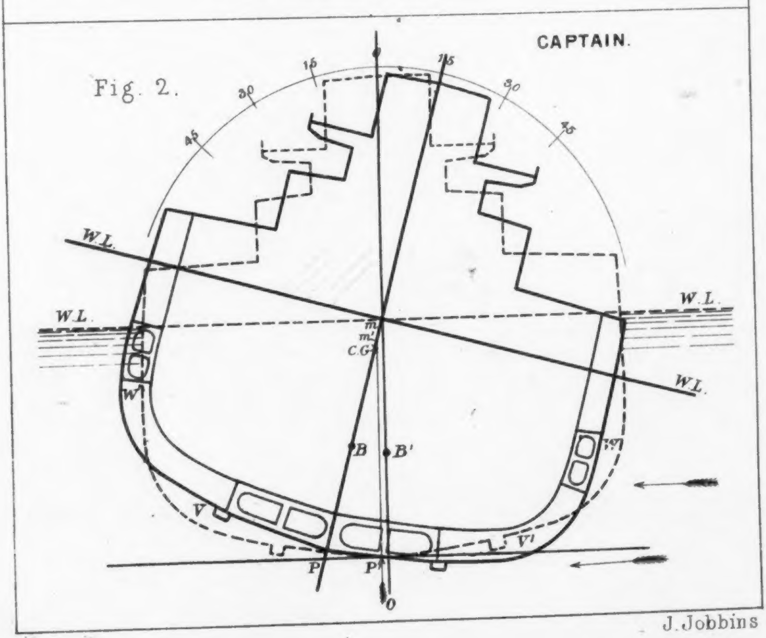
ns


MONARCH.
Fig. 1.
O
0
15
15
30
30
45
45
W.L.
W.L.
W.L.
W.L.


CAPTAIN.
Fig. 2.
15
15
30
30
45
45
W.L.
W.L.
W.L.
W.L.
m
m'
C.G.
W
W'
B
B'
V
V'
P
P'
O

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1stly. Whether she did possess a sufficiency of initial stability; 2ndly, whether the low freeboard was really the sole cause of the catastrophe; and 3rdly, the consequences likely to ensue to other ships, if the faults committed in her design, and that of other ships, be not rectified in them.

For clearness we may state that there are three kinds of stability—

1. That resulting from the form and the vertical position of the weights, termed *statical.*

2. That arising from motions vertical and horizontal termed *dynamical.*

3. That arising from the inertia of weights, resisting motion, or persisting in motion, termed *relative immmobility.*

This last has been lost sight of, and this has given rise to very erroneous views as to the rolling of ships. Their rolling less or more, depends very much on their possessing less or more of this quality. No clear views can exist when these stabilities are confounded or ignored, nor can any attempts to correct rolling be other than empirical, that do not recognize to the full the difference.

To give a ship little statical stability is to injure every one of her qualities, and the idea that in proportion as a vessel is without stability up to a very small limit, she does not roll, is without reason or fact to justify it. An architect who thus designs a ship, incurs a responsibility as respects the lives of her crew of the very gravest kind.

I now propose to prove these points as they were illustrated in the case of the "Captain."

Fig. 1, plate I, represents her midship section, as such is usually drawn when inclined. For conciseness this may be taken as representing all the sections.

Let *A F* be the water line when upright, C E the water line when inclined, G the centre of gravity, B the centre of gravity of displacement when upright, B′ the same when inclined. Then *A M C* and *E M F* will be solids immersed and emerged by the inclination, and x and y will be their respective centres of gravity, m the meta-centre, which in the "Captain" was below the load-water line, a circumstance unknown in vessels of war until within a very few years, certainly in any but unsafe ships, and the fact that the meta-centre was so low in the "Captain," ought to have given an alarm.

When a vessel is inclined, it is considered as if the emerged solid was carried over to the other side and become immersed, and that x is carried over to y, and that the effect of this is to move B to B′, a quantity proportionate to that which these solids, and the distance that x is from y, bears to the whole immersed body measured along a line parallel to the connecting line x and y. Then the whole force of buoyancy is supposed to act up through B′ in a line perpendicular to the mean level of the sea; this will cut the middle line through the ship in m, the meta-centre. If a horizontal line be drawn from the centre of gravity, G, to the perpendicular from B′, we shall have G f, the lever through which the whole force of buoyancy is understood to act, resisting further inclination, or tending to force the ship back into the upright position, just as the force which inclined her, slackens or is withdrawn.

It will be seen that by lowering G to g' the lever is increased, and with it stability, also if the vessel is inclined still further till B is moved over and down to B″, the stability is increased; so the idea is that every vessel increases in stability with each angle of inclination up to a certain point, except her sides tumble home or terminate before she reaches that point.

The above is the generally accepted idea, but it has too much of the harbour aspect truly to represent the facts as they occur.

The summing up of the evidence as to the "Captain's" loss was to the effect that she was upset by the wind and sea conjointly, and this because she was not endowed with a sufficiency of stability, and no doubt this judgment was quite correct.

The weather was described as having been squally with rain, and with a heavy sea.

Others said that there was a confused cross sea, but not heavy, yet that several seas formed into a sort of pyramid; others again spoke of seas breaking to windward.

A witness said about midnight the ship made a heavy roll to starboard, and before she had time to recover herself a heavy sea struck her and threw her on her beam ends; she then turned bottom upwards and went down stern first in about five or ten minutes.

Another says, "all had confidence when she recovered from the first "heavy lurch, but she failed to recover from the second, heeling "gradually over till she capsized."

"She gave a heavy lurch and started the mess traps, and woke "me."

"She recovered from that lurch, and I felt as if I had a good ship "under me."

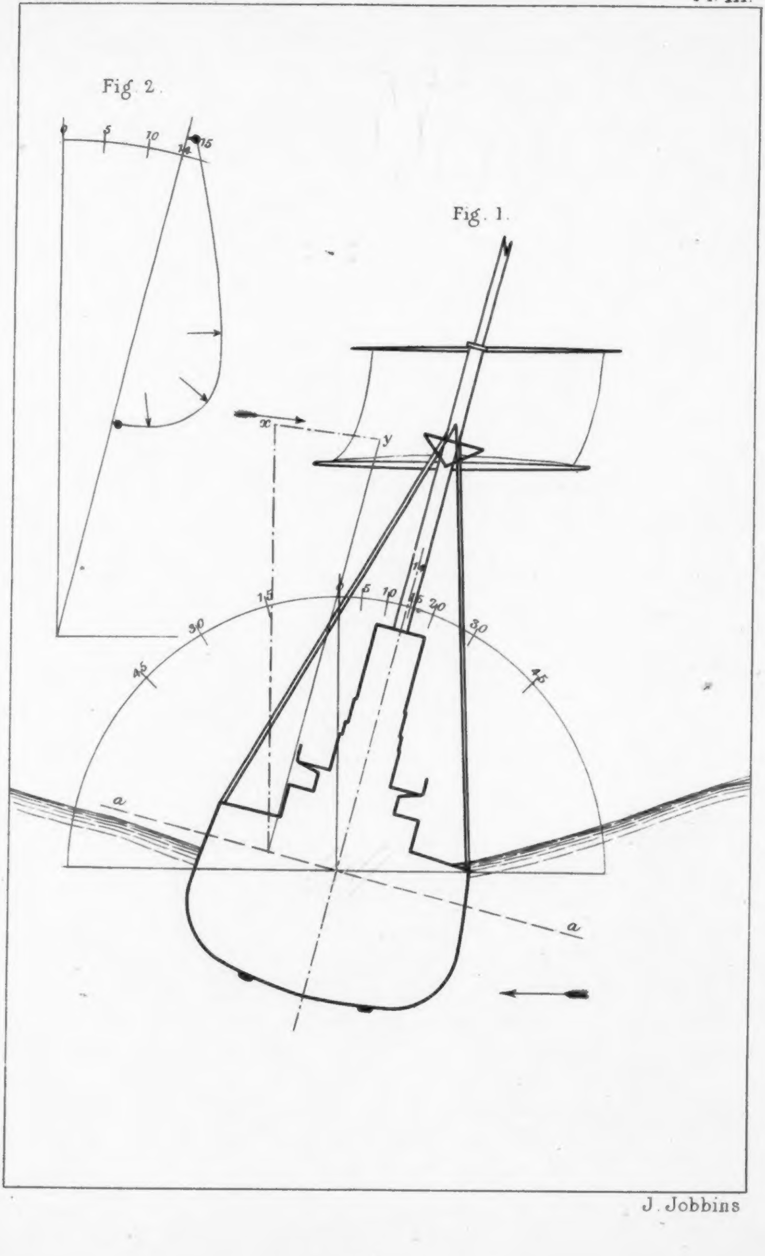
The language of these men does not warrant the idea that she was capsized by a squall, but the contrary, that she was rolled over by the sea.

Still we ought to try to ascertain if there was any influence at work tending to upset her, and whether it operated to that effect before any deficiency arose from her low freeboard, or in other words before the top of her gunwhale was forced under water.

The ship was sailing by the wind, which was strong, and she was under limited sail, but still heeling over from 12° to 14°, not moving much ahead, some say drifting considerably.

It will be seen from the figure (Plate II, fig. 2), which I have placed on a pivot in order to show that by the inclination and immersion of 6½ of side the bottom has been pushed down correspondingly, and that by this the vessel's draught has been increased by two feet. When upright she presented a vertical longitudinal plane of 300 × 25 to resist being driven to leeward by her sails when on a wind; by her inclination to 7°* she pushed her bottom down 1 foot, which gave an increase of

* This explains apparently the anomalous testimony of Lieutenant Rice, that it was more difficult to get "Captain" over from 7° to 9° than from 9° to 14°, a testimony confirmed by others, who stated that it was not easy to incline her to 7°, a statement creditable to Lieutenant Rice's discernment.



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the vertical plane of only 75·5, but when inclined to 14° she pushes the bottom down, increasing that plane by 75 feet long × 2 feet broad = 150, 23 feet below the centre of gravity, equal with a drift of 200 feet per minute to a pressure of 1,200 horse-power, the effect of which tending to upset when the vessel is without much way, and has thus lost her dynamic stability, may be imagined.

This enormous pressure would appear at first sight to be in part compensated for by the pressure on the opposite side, but this is not the case, as when the wind is not on the side, the pressures on the sides are equal. When on a wind the pressure on the leeside is increased by the pressure of the water resisting the whole pressure of the wind on the sails and hull, driving the ship against it.

It will be observed that the vessel's gunwhale is not immersed, and that, therefore, the low freeboard is not answerable for this damaging pressure, which arises entirely in her case from her deficient initial stability and this constantly increasing decrement of actual stability with each increased angle of inclination occurs in all such forms, whether high or low freeboard.

Therefore, to send vessels over to large angles of inclination in search of a reserve of stability to save them from capsizing, is gaining a loss at the further expense of other essential properties of a good ship. Thus as she inclines, the centre of effort of the sails is carried over to leeward (see Plate III, fig. 1), and acts with the lever xy to turn the ship's bow to the wind, to prevent which either the helm must be kept across the keel, or the after sail must be reduced. If the masts are moved forward to try to correct this objectionable defect, other evils are originated, and the balance of sail is destroyed for other angles of heel, or for times when she is nearly upright. The weather helm is thus rendered nugatory, so that with difficulty the ship could be got off the wind to save her from a squall, or from dangers of another kind. The full lines of the lee bow are also immersed, causing an accumulation of water, producing a similar turning to the wind, the ship seeking the line of least resistance.

In the "Captain" I am told they were in the habit of keeping the lee screw going, to throw a stream of water on the rudder to give power to the weather helm.

The "Monarch" also was said to have been hours wearing.

A further injurious consequence of the sails, owing to their great inclination, is the directly pressing down effect from the position the lower part of the sails is brought into. Plate III, fig. 2, represents the section of a sail, shewing the resultant of the wind acting as in a perpendicular direction, pressing the lee side of the ship down, and so tending to capsize her.

Here, again, the delinquent is not the low freeboard, but the small initial stability by which high and low freeboard are alike victimized.

Some have said the "Captain" and other ships have had less stability because they were without keels. The previous arguments establish that all keel has a tendency to capsize vessels that have them when they are sailing by the wind, and that this is invariable except when the moments of the keel from great weight are greater

than the moments of resistance occasioned by the opposition to being driven to leeward by the force of the wind.

On one occasion the "St. Vincent" was given six inches of keel to increase her stability.

Here, again, we may perceive the objection to bilge pieces, unless they are judiciously placed; no doubt they tend to limit the times and arcs of roll, but it may be at the expense of stability by an increase of draft when on a wind, also the peril of rocks and of shoal water may be increased, and from their knife-edge character they may be, if the vessel bumps, driven through the bottom.

There is another serious evil which arises from small initial stability in vessels of the form of "Captain," "Monarch," and others to which I must invite your attention.

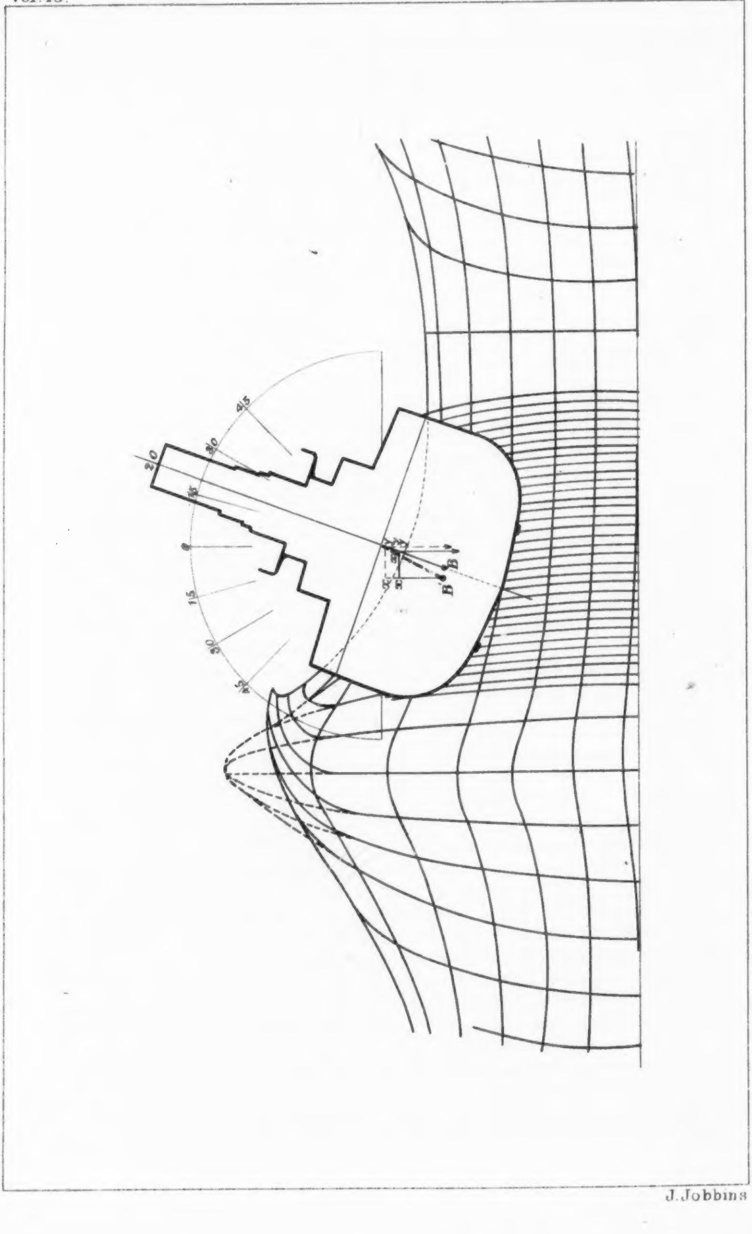
I have placed two midship sections of the "Captain" one over the other (Plate II, fig. 2), to show the real change which takes place in such forms at an inclination of 14°.

It has been supposed that the change of B to B′ is influenced only by the solids of immersion and emersion, &c., and all calculations as to stability are made on that hypothesis.

The intersections of the outlines of the two diagrams, however, will shew plainly that this hypothesis is far from correct, for while there is a virtual transference of x to y, which tends to move B′ over towards the lower side, and downwards; yet there are two other transferences, thus there is a transference of a volume from w to w', which would reduce the horizontal distance of B′ from B, as estimated from the motion of x to y, and there is also a transference of volume from v to v', which would carry B still further down than the ordinary estimate, the more so that the pressures at v are greatly increased by the deeper immersion, and those on the bottom above v are proportionably reduced; the effect of these transferences is to discredit the ordinary mode of calculation, and to place the plane or point, as is assumed, through which the buoyancy acts, less far out from the middle line of the ship, and lower down, and proportionably to lower the meta-centre, and so far further to reduce the actual stability.

The enormous pressures brought into operation by the deeper immersion of the lee bilge (arising from the small initial stability) acting as an upsetting force, increasing as the wind increases, reducing the actual stability with each further inclination, ought for safety, no less than for efficiency up to the point of danger, to be met by commensurate opposing forces, such as proportionably great vertical moments of weights; but instead of that, illustrating the wonted absence of comprehension of the problem, we find the weights vertically centralized, and empty cells or empty space substituted, making a double cause of danger. I may mention, in passing, that the simple cure for this is ballast, which would be most effective in assuring the safety of the vessel, while it would improve every essential quality.

It may be said that these moments of pressure have been considered and are embraced in the calculations of the position of the centre of gravity of displacement; but the greater immersion was *not* contemplated, and the calculations as to the centre of displacement I have



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shewn to be incorrect; therefore no provision could have been made, and indeed the great inclination is indisputable proof that no provision was made.

It is manifest, from a consideration of my remarks on fig. 2, Plate II, that even as a statical question these pressures have not been allowed for; but the action is dynamic, when the light bottom is set in motion by these pressures, they will act with a power of acceleration, and their power to float up the keel is as their small specific gravity.

Thus arising from raising the weights 3 feet or more off the bottom and other centralization of weight, their moments of inertia are utterly deficient, so the increased moments of pressure from the deep immersion are left to unmitigated sway in upsetting the ship or in so reducing her actual stability, as to leave her at the mercy of the first wall sea that crosses her path, all which is aggravated when she is inclined on the face of the wave; as she must have a tendency to slip down the incline by which the tripping effect will necessarily be increased.

Or, to put it in part more palpably:—If we continue the line from M to B′ down to the skin of the ship, we shall find that it divides the cellular bottom with very much the larger portion on the upper or weather side of the plane through which buoyancy acts, and the very great buoyancy of that excess will be acting to overset the ship.

It may be objected that no such consequences as those described, follow from the reduction of moments by the vertical centralization of weights. The answer is simple and complete; if a ship is at a given draught, say even keel, and buoyancy be added as in the "Trincomalee," by throwing out the bow, then, unless the moments of the weights put in to preserve the even keel, be equal to the moment of buoyancy added, it will cause the bow to float up and change the line of floatation.

It has been asserted also with truth, that the extending of weight out to the sides, increases their moment of inertia, and to that extent limits the ship's angles of roll, so also then by a parity of reasoning must an increase of the moments of inertia of weight by vertical dispersion tend to limit the angles of roll, and as the moments of weights resist vertical moments of pressure, so will they resist horizontal moments of pressure. The dispersion of weights vertically performing a double function, and one that cannot be dispensed with except at the expense of efficiency, nor without danger.

The reason why two and three-decked ships, when of a good form, are not deep rollers, is because their vertical moments of inertia above and below are very great in proportion to the disturbing force, and not if it be so, because their centres of gravity are high; no doubt their weights are on the floor, not raised 3 ft. off.

The low freeboard again is exonerated from all blame. I may remark with regard to the rabid hostility to a low freeboard, when a vessel's coals, provisions, &c., are exhausted, she would have a higher freeboard, but does any reasonable man argue that therefore she would be safer? yet such is the logical conclusion from most of the arguments against low freeboards.

The above conclusions are confirmed by the proofs given, that the "Captain" did not possess a moment of stability of 5,700 tons at an

inclination of 14°; for instance, the fact mentioned by Sir Alex. Milne that when inclining near to that, the moving the guns round on their pivots from one side of the vessel to the other, increased the ship's inclination by 4°: also that they were unable to fire at the ships either to windward or to leeward, she heeled so much; an instructive comment on the science that inculcated giving little stability to obtain a steady platform, that is practically depriving a ship of a platform altogether, in the vain hope that on some favoured occasion she might have an opportunity of firing to advantage.

There is another point of great importance illustrated in the "Captain," and doubtless in many other ships, the fate of which is unknown.

Plate IV represents a ship heeling over considerably under the pressure of her sail; a wave is approaching, and as the power of its vertical height is transmitted even when it is distant from her, the side nearest the wave-ridge rises, inclining her still further, but lifting that side and the centre of the ship to a higher level as it comes towards and up to her side. As the crest approaches, the power of the vertical height and its action increases; then when the crest seems about to break on board or against the ship, if the water accumulates at that or the upper side, it will move the centre of effort of buoyancy over with it from the lee or lower side to the upper side: in other words, it will take the prop that was supporting her from under the ship on one side to become a force on the other side to throw her over, and as the wave passes across unresisted, even though it did not strike her as it did in the case of the "Captain," it would carry her over with it.

This no doubt was the case of the "Captain," and the process was facilitated by the deep immersion of the bilge, which as she with little head-way was drifting to leeward and slipping down the face of the wave, would trip her up, and then the active agency of the light bottom unopposed floating the keel up, would complete the overset.

The sails no doubt would have brought her mainly into this dangerous condition, but their power must have been greatly reduced by the great inclination.

Thus by a combination of adverse circumstances, given power to by the absence of initial stability, the centre of gravity was left without support, therefore the whole weight of the ship, and the whole force of buoyancy formed an adverse couple to turn the ship bottom up, with a power that no amount of side could possibly have averted.

Heeling so much, the sea had little to effect; so both a short time and a small action were enough to upset. In proportion as the stability should be increased, the sea would require more power and more time to effect an overthrow; the probabilities would be then, that owing to the lapse of time, the sea would have passed the middle line of the ship and commence to act in righting her by carrying the line of buoyancy over to the low side. The danger is greater in proportion as the stability is deficient.

In this process of accommodating herself to the wave, a ship will be the more readily and extensively inclined as her breadth is greater,

because of the greater leverage of the half breadth, and the facility of inclining her will be in proportion as the centre of gravity is higher.

It should be stated that a gentleman of great mathematical attainments objected to my representing the direction of the upsetting force as vertical, alleging that it could only be perpendicular to the wave surface, as that was the resultant of the motion of the particles in the wave on which the vessel was. I have given in Fig. 3, plate I, what is represented to be a diagram of a wave by Mr. Scott Russell, showing the path which the particles take, to be different from that stated; whichever view is taken, is a matter of no moment, for the thrust must be resolved into two forces, if it be not all vertical; my representation therefore will be correct, with the addition of a small lateral thrust, which would rather accelerate the catastrophe if one view was correct, and would avail nothing if the other was.

I have shown that for several reasons, from giving little initial stability, there necessarily arises a further reduction of actual stability, or in other words, the increase of stability which vessels are sent over in search of, has no existence in fact, and therefore that which the public have been invited to place confidence in, is to a very great extent moonshine. Therefore, as the stabilities of many of our ironclads are over estimated, there is no margin with which to play, without very great danger to life and to public interests. This I propose to illustrate by the "Monarch," which I may presume is esteemed by her designers as the model ship.

The public were informed that the "Monarch" possessed a moment of stability at an inclination of 14° when loaded of 6,100 foot-tons, but as her meta-centric height would be reduced when light to 1·28, her moment of stability would be only 3,050 foot-tons at 14°, and when inclined to the top of *her* gunwhale, it would then be not more than 6,300 foot-tons; but on the hypothesis that the "Captain" was upset by her sails, a force greater than her maximum moment, viz., 7,100 tons, we do not know how much must have been employed to overthrow her, therefore too much also for the "Monarch," and *she* would be upset.

I may here ask, would anyone be justified in sending the "Monarch" to sea unchanged, to the peril of so many lives, how much less justified, if my demonstrations as to the over-estimates of stability of that and other ships, together with the danger which arises from seas under the circumstances of small initial stability—are accepted.

Fig. 1, plate II, represents sections of the "Monarch" one over the other at load draught nearly inclined to an angle of 14°. From this it will be seen that the defects in the "Captain" appear in the "Monarch" in a high degree; thus there is a greater immersion of bilge, which besides the highly objectionable increase of draught, entails a reduction of the actual stability, and occasions an enormously increased tripping pressure on a wind, and worse on the face of a wave, all tending to upset with a force equal to about 1,700 horse-power, thus impairing with this dangerous reduction of stability, all the essential qualities of a man-of-war; besides those mentioned in the "Captain," this further, that when the helm is put over to turn the ship round,

she heels over proportionably to her deficiency of initial stability and the power that ought to have been employed in giving motion or living power to the sides and ends is absorbed in producing inclination, and so that when her way is lost or nearly so, and the power of the helm small, these have no momentum to carry her round over the *dead point*.

The centre of gravity being high, and having motion, tries to move on continually in the same path, while the immersed body being forced round by the stream on the rudder, tries to move in another direction. It will be seen from Plate II, that the effect of this also is to present an irregular figure, which retards the motion of the ship both in going ahead and in turning.

This will account in some measure for the report made by Sir T. Symonds, that neither the "Monarch" nor "Captain" could stay or wear with certainty without the employment of steam, while the "Monarch" is said to have taken three hours to wear, nor can we overlook that as a consequence of their little initial stability both the "Monarch" and the "Captain," though spreading a large area of sail, were reported as bad sailers. Sail is effective in proportion to the greatness of stability, and the effective force decreases with each additional angle of inclination, which again acts injuriously, necessarily on the form, the rudder, and the position of the sails.

So far we have not found anything to warrant the practice contended for and illustrated so fatally in many ships,—that of giving them little stability, but the reverse; it is, however, just that we should examine the reasons and alleged facts offered in justification of a course so contrary to all previous experience.

The idea is, that in proportion as this quality is reduced, the ship will roll less, and the danger will be less of consecutive impulses from following seas accumulating, so increasing the angle of roll of the ship till she is rolled over.

It has been expressly stated that if a ship were without stability altogether, the largest wave that could occur in the Atlantic would not roll her; this idea seems to be deduced from the supposition that a ship is like a pendulum which is freely suspended, and if she possess stability, is set in motion by a wave, and receives under certain conditions successive increments of force from each succeeding wave, till the angle is increased to a maximum that may be fatal in amount.

The answer is, that a ship is in no wise like a free pendulum, nor is she in the main allowed to oscillate, except to order, under the influence of two opposite forces.

When a wave approaches a ship at rest, and while it is yet distant, she begins to incline, and as it approaches nearer, she inclines still further, not simply by a horizontal impulse, but by continuous vertical forces that are lifting the side of the ship and the ship, and inclining her together; finally having lifted her high enough, it passes under her and tosses her over or through its crest on to the back of the wave, when the middle line of the ship having past the crest, the higher vertical forces commence to operate on the other side, destroying the living force that she had acquired in one direction

from the face of the wave, and having done so, gives her an opposite motion, which is continued and increased down the back of the wave, and until the approach of another wave face, which in its turn destroys the living force imparted by the back of the wave, and imparts its own force in an opposite direction; and so on while the ship is in the midst of waves, she is continually subject to vertical or oblique forces, and though these may apparently be independent oscillations depending upon her form and the disposition of her weights, yet is she always moving under compulsion.

Had there been any truth in the wave cumulation hypothesis we should have found some evidence of it in every table of simultaneous angles of roll taken in every squadron for years, but it does not appear in any, that is to say if it were true, we should find, I suppose, A in her first roll, B in her second, C in her third, D in her fourth, E in any roll you please, for we have no tallies to mark the next series, the ships would come out, nobody knows when, and each table must emphatically express *higgle-de-piggledy*. If any gentleman ever saw such a table, I never did, and therefore must ask him to eliminate order out of such. Everyone knows that every table, as a rule, marks the distinct characteristics of each ship, and when there is an exception we conclude that something is wrong, the eye, the battens, the pendulum, the time, or an intermediate and discursive wave.

On the other hand, we find admirers of the hypothesis, and acting on it, though facts belied it, recording such as the following, "ships "rolling according to their weights, the heaviest least, though the "mathematical argument takes no cognizance of weight."

The late Constructor of the Navy, as reported in the Transactions of Naval Architects, said, "The 'Warrior' has more stability "than the 'Minotaur,' and the 'Minotaur' more than the 'Achilles,' "which corresponds with the fact that the 'Achilles' is the least "rolling ship of all the larger ironclads yet produced, and completely "justifies, I think, the attempts which have recently been made to "*get the centre of gravity of those ships higher in order to check rolling.*" In his work "Our Ironclads," he gives a number of extracts from reports on various ships, showing the angles to which they respectively rolled, illustrative of what he was aiming at by getting the centre of gravity of those favoured ships higher.

"These illustrations" (given in Table A), he further writes, "will "serve to shew the desirability of making the distance between the "centre of gravity and the meta-centre as small as is consistent with a "proper amount of sail-carrying power, or stability, when an iron-clad is "being designed, and this course has been followed in all recent ships." Speaking of the "Invincible" class, he writes, "The probability, "amounting almost to certainty, is, however, that these upper-deck "batteries alone would make the ships steadier, as they bring up the "centre of gravity, although, on the other hand, the great sail power of "these ships, necessitating as it does a considerable amount of stability, "has put a limit to this improvement."

Now the answer which facts give to the above is simple and without exception, raising the centre of gravity, never reduced the arc through

which a ship rolled, and every ship rolls through larger arcs as she lightens, and raises her centre of gravity, and if reports be true, the "Monarch," on her way home from America, rolled through 35°,—no doubt through some indefinitely large angle, if not that, when she was light.

Indeed the late Constructor of the Navy accepts this view, though late, as is evident from his letter in the "Times" of the 7th of November, when he began to entertain apprehensions as to the "Monarch," where he writes of her, "When to some extent lightened "she has that degree of stability which is ample for safety, but "moderate enough to ensure steadiness of gun platform. When quite "light, &c., she still has sufficient stability for mere safety, but it "would contribute to her comfort and steadiness in a gale of wind under "canvas to admit water ballast into a few of her lowest compartments "for which provision has been expressly made in her design."

The centre of gravity of many ships has been expressly raised to ensure a steady gun platform, and it is proposed to extend that to other ships to cure them of uneasiness, and yet we are here told of provision being made to lower the centre of gravity for the purpose of obtaining comfort and steadiness.

Nor is there any justification for the statement that the old wooden vessels, when placed on an equality, rolled more, or indeed as much as the ironclads, or rolled more because their stability was greater. In the squadrons that were out in 1846-7 perhaps none had greater stability than the "Trafalgar," and she was the easiest and rolled through the least angles. There can be no doubt as to the great stability of the "Phaeton," and there can be no doubt either as to her easiness and small angles of roll.

I have tabulated the extracts given in "Our Ironclads," and have added some further information to shew what really is the cause of ships rolling more or less. I have arranged them in the order that the vessel having the largest disturbing force—which is large proportionate breadth—shall stand first, the ship with the least, last, and it may be seen that generally this is the order in which they roll, more or less, the exception to the rule arising out of the difference in the measure and number of limiting forces.

TABLE A.

Name of Ship.	Angles of rolling as given in Mr. Reed's work on Ironclads.																			Mean draught of water.	Proportion of breadth to length.	Displacement.	Weight of armour.
"Edgar"	14·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	$\frac{1}{39}$	..	..
"Pallas"	..	17·3	..	..	..	..	..	..	..	..	..	..	..	12·	13·	..	..	..	..	24·2	$\frac{1}{45}$	3656	560
"Lord Clyde"	..	16·1	12·3	19·	47·	..	6·5	5·5	21·5	6·5	21·	..	..	27·	13·	..	..	..	6·7	25·	$\frac{1}{47}$	7675	1379
"Lord Warden." ..	..	..	..	..	..	11·2	4·9	12·	9·1	4·9	14·5	..	..	12·	4·7	..	..	..	..	25·8	$\frac{1}{47}$	7675	1379
"Prince Consort"..	11·7	..	..	..	..	..	..	..	..	..	..	9·	10·4	11·	5·7	10·3	7·7	3·1	..	25·4	$\frac{1}{47}$	6600	941
"Royal Oak"	..	..	..	..	..	..	..	..	..	..	..	10·	10·	11·	5·3	9·5	14·3	7·7	..	24·8	..	..	930
"Defence"	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8·8	11·2	9·4	..	24·10	$\frac{1}{52}$	6000	607
"Bellerophon"....	..	6·6	6·8	15·	29·	3·	..	..	..	..	9·4	..	..	8·6	..	2·5	5·4	..	4·	24·3	$\frac{1}{53}$	7053	1089
"Warrior"	10·2	..	..	..	..	6·1	2·8	..	7·5	2·8	12·6	7·	5·7	9·	6·3	2·5	9·3	1·4	..	26·	$\frac{1}{65}$	9020	975
"Achilles"	..	6·6	5·8	13·	..	2·2	..	..	5·9	..	6·3	6·	2·5	5·9	..	2·5	5·2	2·1	4·	26·3	$\frac{1}{63}$	9525	1684
"Black Prince" ..	11·05	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	26·6	..	9250	975
"Minotaur"	..	..	4·8	12·	19·	2·7	..	..	..	..	6·2	..	..	3·1	..	2·5	*4·3	..	..	26·5	$\frac{1}{67}$	10230	1776

"Lord Clyde's" rolls made to appear more than they ought to be, because of using a pendulum. "Prince Consort's" rolling is said to have been aggravated by the use of pendulum. * The pendulum gave "Minotaur" 8·2 on this day.

By reference to Plate IV a ship in the midst of waves, it will be seen that the disturbing force is the wave motion, that she is continually under the impulses of vertical forces that are in excess one side over the other, first one side then the other, as the wave passes across her path, and it is equally obvious that the wider the ship the greater are the number of these impulses she will be subject to at a given time, and the longer time the wave will be in passing across her, therefore the wider the ship, all other things being equal, the greater will be, not only the disturbing force, but also the power through which it disturbs, which may be much aggravated by a rise and fall of the centre of gravity, and this is fully shewn by the table. The exception arises from the difference in the measure of the limiting elements, great distribution of weights vertically and laterally, low centres of gravity, great vertically longitudinal area, which may be increased by bilge-pieces or sliding keels, if done judiciously, all these tend to keep down both the angle and times of roll. I have not the data for giving explanation in detail of the exceptions to the rule, but I may mention two ships as an illustration.

The "Achilles" and "Warrior" are of the same dimensions in the main, but the former carries 1,200 tons of armour, the latter 975, making a large difference in the stability of immobility in favour of "Achilles," as 144 to 95.

Again, the bottom of the "Achilles" is more filled out below, to obtain greater displacement, which would increase the vertical moments of her weights, and give her a further addition of stability of immobility over that of the "Warrior."

Then the greater weight and greater immersion of $3\frac{1}{2}$ inches, of 73 feet of vertical longitudinal area, 25 feet below centre of gravity, would certainly tend very much to diminish the time and arcs of roll of the "Achilles."

The arresting and righting force of the wave is one of those providential arrangements that saves every ship in her turn from being rolled over, and especially is it so in the case of the ironclads, and that because of the enormous living force that there is stored up in their iron sides, which but for being thus arrested and rolled back, would be rolled over; and if from want of a sufficiency of initial stability, the sea finds them inclining much under sail, it will make as short work of them as it did of the "Captain."

It is also important, and contributes to the safety of ships, that the back of the wave is lengthened by the carrying over of the wave-crest by the wind.

Even had there been any truth in the idea on which the Constructive Department has been acting, as it had not a single fact to authenticate it, it was most unjustifiable, on a mere fancy, practically to deprive ships of their one vital quality; and the less pardonable, that they had such an easy ship as the "Minotaur," with so much stability, as compared with that which they have given to later vessels.

Then the small measure they proposed to leave, viz., a moment of stability that shall be just in excess of the moment of sail, is palpably inadequate, for it must be obvious from Fig. 1, plate III, that a ship on a

wind is under the influence of three inclining forces, the moments of sail, the wind on the hull, and that of the lateral thrust of the water resisting drift, which must of necessity be a large function of the other two, and to neglect it, and not to provide for its action in the amount of stability, is to endanger the ship. The truth of this was illustrated in the "Invincible" that was to prove the contrary, for she heeled 17° without any sail, immersing deep her lee bilge and with only a small amount of wind.

In their fears of a possible evil that had never been known to occur, they adopt a course that should guarantee danger. In their horror of a phantasy, a possible accumulation of wave force that might possibly eventuate in an upset, they adopted a method beyond all doubt eminently calculated, not simply to check rolling, but to put a final end to it in all ships operated on, for it only requires ordinarily favourable circumstances for each to effect a roll over.

Happily there seems to be an awakening from the fond fancy that such extravagant plans as I have described had their origin in science, and that 200 and 300 tons of ballast have been placed in several of these ships to save the lives of their crew.

It may be thought that I ought to dwell on the special characteristic of the "Captain," not simply as so much too much has been made of it, but because it involves an important principle in naval architecture, I mean the real effect of a *low freeboard.* As to turrets or broadsides I give no opinion, as I have not studied the subject; it is as an architectural question that has been viewed by controversialists, as the shields were by the combatants of old, each looked from his own stand-point, and pronounced it black or white, that I wish to deal with it, because in the contention the public suffers and *sailors perish.*

It is impossible to do justice to the subject without going more fully into fundamental principles, which I feel to be more imperative to do, as those I am about to enunciate are new, and if established, as I have no doubt they will be, they will settle definitively many disputed points, and show the fallacy that naval architects have been in the habit of accepting as truth. It is clear that there is something radically wrong, for it never could have been intended that the "Inconstant" should have heeled to 17° without more than an ordinary pressure of sail; or that the "Invincible" should have heeled to 17° without any sail. There must be something wrong in the *mode* of calculating the stabilities of ships. I do not believe that such extensive mistakes could have been made in calculating stabilities in any other way.

So far as I have shown, many ships—yes many—in the Navy appear unsafe. For the importance of the subject therefore give me your attention for a short time longer, and I will establish that in everything, I have understated the evils.

If a rectangular box be pressed down perpendicularly into water, the whole of the supporting resistance will be against the bottom, the pressures on the sides will balance each other, being equal and opposite; their tendency being to steady the box, not to support it. The sup-

porting pressures will be all in vertical lines in opposition to the force of gravity or other depressing force.

These forces may be summed and treated of as if they passed through the centre plane of the box.

So also with a ship, differing only as her form differs from the rectangular form of the box; then some small portion of the supporting pressure, however, will be distributed on those portions of the sides that are not vertical.

We may assume the case of a ship floating upright, the pressures in a state of equilibrium, the weight and the buoyancy being equal and opposite. If the forces be supposed collected into one plane, it must be that which passes through the centre plane of the ship.

We may assume the centre plane to be in the main cross section of a ship, and further, for argument, we may assume that it represents the whole of the cross sections, and that the whole weight is collected at the centre of gravity, which is a point in the plane which divides the ship in the middle; also, that the whole of the forces of buoyancy are collected into the same plane, acting with an equal force and opposite direction.

There can be no doubt that the most essential properties, and even the security of a ship, must depend upon the proper adjustment of these centres or planes; therefore the accurate determination of the planes and directions of these forces, becomes a question of vital importance.

The difficulty of ascertaining the centres of gravity of all that goes to make up a ship and its lading, and their distances from a common point, is such as to prevent more than an approximation to their common centre of gravity directly. This, therefore, is sought to be done indirectly by methods which are more or less dependent upon the position of what is termed the centre of gravity of displacement, on the erroneous supposition that this is *the* centre through which all the forces of buoyancy pass. Yet, except when the ship is upright, these forces or their mean, do not pass through this point, nor can they, therefore accuracy is by these methods impossible.

The centre of gravity of displacement is determined on the assumption, that as the water displaced was homogeneous, so the immersed portion of the ship's body may be treated as being so also. In this are implied several erroneous assumptions, viz., that the immersed body is homogeneous; that it is of the specific gravity of water; and that the pressures distributed on the bottom can be treated of, as if collected at the centre of gravity of displacement, as if it were with every change, still the centre of the forces of buoyancy. Now, these errors cannot fail to vitiate all calculations as to stability and rolling motions.

Errors respecting the amount of stability have been hitherto on the safe side, hence greater evils have not occurred; but the introduction of iron, and more especially of heavy armour, has changed all these, making it imperative to investigate all the new conditions involved in the change.

Many facts and circumstances will bring to the mind of the sailor

proofs that the pressure of water on the lower portions of vessels' bottoms is greater than is generally supposed.

Many will remember that the flag-ship on the South American station, the "Spartiate," was sent home because she leaked so much; though the leak proceeded simply from a short seam having been left uncaulked; and so also the "Daring" was endangered from little more than a spile hole low down, difficult to discover even in dock. In my earliest recollections of sea-life, is the story of an Irish lieutenant, who by way of encouraging the men at the pumps, said, "Hurrah, boys, the more that comes in, the less there will come." In this he stated a philosophic truth, in an Irish way; viz., the more that flowed in, the less would be the height of column outside to force it in, and it would not flow in so fast, thus they would be able to prevent the water from gaining on them; all this tends to establish that the pressures on a ship's bottom, are principally on the lower part.

Treating the immersed body as if it were homogeneous leads to an error greater in amount in proportion as the body is less and less homogeneous, for if we imagine cubes of equal volume and of equal specific gravities, viz., that of the surface-water, to be started together from various depths, they will rise to the surface with varying velocities, as they may have been placed deeper in proportion to the greater or less pressure they may have been subject to from greater or less immersion.

If now we take cubes of equal sizes, but of different specific gravities, yet all lighter than water, and start them from the same depth, they will rise to the surface more and more rapidly as their respective specific gravities are less and less, indicating a power of floatation proportional to the smallness of their respective specific gravities.

If also we place a weighted cube at the bottom of a trough of water, with its heavy side down, it will float up without turning; if it be reversed, and started with the heavy side up, it will turn over in its passage to the surface; or if we take a cube heavier than water, and place the heavy side down, it will not turn over, notwithstanding the resistance offered by the water to its descent; on the contrary, if the heavy side be placed uppermost it will turn over, indicating that when not controlled by a greater force they manifest their distinctive properties. Nor will they be denuded of their peculiarities in this respect if we attach them to each other; they will act each according to its properties as before, but the separate effect will in part be obscured, for the general result will be that the rapid risers will be retarded by the slow, and the slow will be accelerated in their motion by the fast, until there is a mean resultant of these varied velocities.

Ships are made up of sections and of parts of varying and unequal specific gravities, and differing one ship from another, therefore made up of parts having different floating powers.

While the ship is upright, the collective weight acting downwards upon the general upward pressures, forces the parts to act in one plane as, though they were of all of one mean specific gravity, viz., that of the water in which she floats; but the moment the ship is inclined from the perpendicular, the balance is destroyed, and the varied powers of floata-

tion in the several parts or sections of the ship assert their prerogative, and operate as truly as if they were unconnected, though not as perceptibly, because they are tied together, and because the particular effect is covered up in the general.

The solid bottoms of oak ships, made heavier by caulking and bolts and ballast, with everything heavy, placed on the bottoms, had no tendency to float up, while the body became lighter as it approached the load-water line; their immersed portions were so treated as homogeneous, though erroneously so; the error was, perhaps, on the safe side, that is, it tended to lower the estimated height of the centre of effort of buoyancy as much as the other error, that of treating the pressures as gathered into a centre, tended to raise the estimated height.

By the introduction of iron these errors are both on the same side, and therefore proportionally dangerous.

1stly. Because equal strength with that of wood can be obtained with a much less weight of iron, the hulls of iron ships in general, and their bottoms in particular, are much lighter than those of wooden vessels, which has been aggravated in the Navy by making these bottoms unduly light, and the tendency has been to make them lighter.

2ndly. Because of the great weight of armour in the vicinity of the water line increasing enormously, the weight of the upper immersed portions necessitating a compensating reduction of the weight of the lower portions.

And 3rdly. The introduction of large *empty* cells above the bottom, the effect of which is to raise the centre of gravity and give greater power by increased leverage to this empty bottom, cellular or otherwise, low down and of little specific gravity, therefore possessing a power vastly greater than that of any other portion of the body.

In fact the tendency of these cells cannot be otherwise than that of seeking to escape, so that at each roll they endeavour to throw the weight off their backs, and rush to the surface; unable to do this, from their connexion with the vessel, they tend to turn the vessel over, and with every increase of motion, their accelerated force adds to their power and danger to the ship, and so proportionably it requires little additional force, when provision is not made to control their efforts to overthrow the ship.

I said that the centre of gravity of displacement could not be the centre of buoyant pressures. I now go further and say that these pressures could not be collected at or supposed to pass through a point, for they are all exerted on the skin of a ship, and act with increased intensity below, and their direction is normal to the varied curves of the bottom. The extended lines of these pressures might meet in a vertical plane, but the measure of their vertical action could be obtained only by resolving them into vertical and lateral thrusts. The vertical thrusts might be collected into a perpendicular to the earth, but having their origin in a point in the lowest part of the skin of the vessel, of every section, but not in a point in the vessel above the bottom. Now these pressures have their moments, according to their distances from the water line, and they act with the power of the varying specific gravities of the body on which they operate, and are

effective for good or evil in proportion as the moments of the parts opposed to them are in excess or in deficiency of their moments.

It may be said that this is not so, for that as respects the weights, they are all estimated for in the mean height of the centre of gravity, and if this is at the same height as in the wooden ships, even though the weights are differently distributed, the result will be the same.

It was stated by Mr. Reed, in evidence at the court-martial on the loss of the "Captain," that the actual position of vacant space in the ship has no effect which is not comprised in the calculations made on the centres of gravity or buoyancy.

Surely this is begging the question; the knowledge, if it may be called so, of the position of the centre of gravity is dependent upon that which itself is unknown, and if known, then only in the lump, so if it were thus determined, this would be no proof that the effects of the moments of the weights and buoyancies are duly estimated.

Obviously it is not so, as there may be an indefinite variety in the modes of distributing the weights, and yet the centre of gravity may remain at the same height: the result of this often is, that the same ship's behaviour is so different, that she appears not to be the same ship, yet the difference is only in the vertical distribution of weights from the same height of centre.

The more the weights are brought in towards the centre of the ship, the less is the power that will be required to move her round, whether that centralization be in the vertical or horizontal planes, or both. From this it follows that the more the weights are brought in or up to this centre, the more power will the forces of pressure exert towards upsetting, when the vessel is inclined, and the more power will the lateral forces exert to incline when they are in excess one side over the other, as when a ship is on a wind.

We can imagine a ship built up with her sides and bottom, as light as possible, and all her weights collected in the centre at the water line. Such a ship would be tossed about by every small force that she was brought into contact with, and yet the spaces and weights would "be comprised in the calculations on the centre of gravity or buoyancy." Distribute the weights uniformly, laterally, and vertically, and the inertia of these now will be increased as the square of the increased distance from the centre, and the same pressure will no longer move her to the same extent. And yet the calculations alluded to on the centre of gravity and buoyancy will remain the same.

It is overlooked that the portion of a ship that is influential on her motions and qualities in reference to water-pressures must be that which is immersed, and that this possesses its own centre of gravity and tends to follow its own laws and to obey the pressures it may be subject to; it may be overruled but it acts nevertheless and produces results, though they may be obscured in the general result.

Then as to the centre of pressures of buoyancy, it may be said that the floating power of the several parts of a ship are truly determined by the ordinary method of determining the centre of gravity of displacement; but this is again to beg the question, since it has been shown that the centre of gravity of displacement is not the centre of

effort of buoyant pressures, nor can the mean of these pressures of buoyancy pass through the centre of gravity of displacement, except when the vessel is upright; nor is it even the centre of gravity of displacement, that is, the centre of the displacing body, nor is it the centre of pressures that were on the displaced water. The direction of these is so varied, that it is impossible they could meet except in a plane. Thus, if we immerse a cylinder to its centre, it is obvious that the pressures by which it would be supported would be in the direction of its radii, and could meet only at its centre; but the centre of gravity of displacement of that half cylinder would be ·42 below that point, and to treat these pressures as has been the practice, in the lump, is something more than crude, therefore they must be resolved into vertical and horizontal thrusts. These might be collected into their respective planes, but cannot be treated of correctly, as if collected to a point (see Fig. 2, plate I). This obviously must be so, for if the cylinder were hollow, but of the same weight, then its centre of gravity would be moved down to ·63, but this would not make any difference in the locus of, or direction of the pressures; unresolved, they would meet in the centre of the cylinder; resolved, they would meet in planes intersecting each other, yet C would be the centre of gravity in the first, and C′ that in the second case on the old method. It is obvious that whatever the form of the immersed body may be, the pressures must be on the outer skin, and be perpendicular to each part, and the thrust must be resolved into horizontal and vertical forces; those horizontal forces, then, may be disregarded, first, because they balance each other on opposite sides of the ship; and secondly, because they bear no portion of the weight of the ship.

All the calculations therefore which have depended on the hypothesis that the centre of gravity of displacement was also the centre of buoyant pressures, must be erroneous and utterly unreliable; the question, then, that suggests itself is, what is the operation of this new view?

Without a direct calculation, it would be impossible to say exactly, but the results of the old method may be used to give an approximate answer and to show its tendency.

There will be a correct distance, that the plane of pressure will be carried out from the middle line by a given angle of inclination, let the distance be supposed, and let that distance be taken and measured off from P,* the first centre of pressure towards P′, and assume that is the new centre; then from that point, draw a line perpendicular to the water line, and it will be found (Fig. 2, plate II) that it cuts the line through the middle of the ship lower down than in the supposed metacentre and at M′, which is the true meta-centre, and which proves that all stabilities determined by the old method are overestimated; this will account for the fact that ships supposed to have some stability are now found to be very deficient. This method termi-

* Though P is the centre for the midship straight of breadth, and though each other section has its centre higher, yet they fall into the plane, which is a perpendicular from P, and because higher, could not be brought down to a point below, nor would a mean be correct, as the pressures are unequal.

nates the vagueness and uncertainty that necessarily attached to all calculations based upon the unknown and clearly untrue; and with its adoption must terminate those mere approximates that are always so dangerous. This method also terminates the mathematical calculations as to the oscillations of ships, on the supposition that they are like pendulums, or their motions analogous; it is far otherwise, they are borne up by pressures, the mean centre of which is constantly moving as the water or the ship moves, and makes a circuit of varying shape and distance round a point at the lowest part of the ship's bottom.

The main truck, in its motion through the air, makes a figure somewhat like it, but enlarged.

It needs no demonstration to prove that the lighter the bottom on which these forces operate, the easier they will force it out from underneath the superincumbent weight, or in other words the higher the centre of gravity, the greater will be the leverage to move it, or the supporting buoyancy from underneath it, and the greater, therefore, will be the arc of roll, also the less the weights are distributed vertically, which is tantamount to the levity of the parts without such weight, the greater also will be the angles of inclination and arcs of roll with a given height of centre of gravity.

Treating the pressures of the water as being always on the outer skin of the vessel, will lead to a correct determination of the position of masts, the lateral and vertical moments of sail, and to an approximate measure of the dynamic stability from horizontal motions, if not also to a determination of the direct resistances.

From considering the subject thus, it also appears that the rise and fall of the centre of gravity, which produces the most dangerous and violent motions, is not confined to inequalities of the solids of immersion and emersion, but obtains in vessels of the form of the "Monarch" and others, and will account in part for the difference in the angles of roll between two ships having a general similarity and distribution of weights where this form exists in a greater or less degree.

I suggested the necessity for a method for determining the pressures on ship's bottoms, and for summing them up so as to determine the position of their mean centre at any given time or position of the ship to Mr. Oliver Byrne, and he has investigated the subject mathematically, and is prepared with a formula for the purpose.

It may be argued that according to the above, this may answer for future designs, but if all estimates of stabilities are excessive, and if some ships have practically reached the enviable point when they were not to roll, that of being without stability and yet do roll, and moreover roll over, what is to be done? there is an immediate need for action!

If report speaks truly, the common sense which was so contemptuously thrown aside for a hybrid science, has dictated ballast, and it is being put into many ships, but should be placed in many more; further, there must be an extensive vertical distribution of weights, and notwithstanding the prejudice there is against ballast and masts, and notwithstanding the latter are being reduced, I affirm that both ought to be employed.

But the question is, for the present how much must we be guided by the repudiated practice?

In the case of the ships referred to, there can be but one opinion as to the propriety of placing ballast in them, but to do so by all ships, is objected to, as I conceive, without judgment.

A small quantity of ballast even, if low down, is a mighty power, and I do not know how any sufficient vertical moments are otherwise to be got, and these are indispensable to a safe and efficient ship. Obtain the stability by breadth, and you will increase the disturbing force and angle of roll; obtain it in part by ballast, and you will take from the disturbing force and add to one of the forces that limit the angle of roll, while you are increasing the safety and general efficiency of the ship. Ships cannot with safety be left to the chances that will arise from having movable ballast. Ballast, which may be in pigs or iron, employed in giving additional strength to the bottom, from its great specific gravity and compactness, will give advantages not to be obtained from anything else; any space is available, and it can thus be placed lower, and thus by lowering the centre of gravity, greater stabilty and greater moments are obtained. Such ballast does not interfere with accommodation, and such addition of weight is an advantage rather than otherwise, for if the sails have to drive it, they are made more effective, and their power is enhanced more than they are taxed for work; in driving and in limiting the arcs of roll, the resistances, whether propelled by steam or sail are greatly reduced, while the safety that is obtained by its use is so valuable that all other disadvantages spoken of might well be disregarded, even if they did arise.

Some have thought that masts, except in vessels propelled by sails, are an unmixed evil; on the contrary, the action of the masts alone is very important in limiting the times and angles of roll; their great length involves great moments of inertia. It may constantly be seen that when a ship has turned to roll back, the masts have not finished their roll, they have been lagging behind and taking up living force from the hull, but also retarding its motion; now this living force has to be given out before the direction of their motion can be changed to that of the ship, in doing this they help to stop the ship from going too rapidly down the back of the wave from a wave crest, and if sail is on them so much the easier for the ship, and though it might be thought that the stability should be increased when sail is used, yet the moments of the masts would mitigate and prevent undue velocity of motion.

I am satisfied that the amount of stability which is necessary for complete efficiency will be ample for carrying sail; the weight of masts 150 tons in a vessel of 5,000 tons displacement is nothing in one sense, but in another like ballast they are useful, almost necessary in order to obtain the proper vertical moments of inertia for ease in due proportion, and they are, with very rare exceptions, elements of safety, and are otherwise useful.

I may now revert to the low freeboard in the "Captain," and the loss of stability it entailed; this has been greatly exaggerated, and

the quantity has been incorrectly calculated, the comparison drawn between her and the "Monarch" being unfair. Thus it was stated that if two ships have their centres of gravity equally high, and the one has a high and the other a low freeboard, the latter will be capsized first; this is a trueism, but it was untruly implied that this was the case with the "Captain" and "Monarch." The "Monarch's" centre of gravity was about 2 feet higher than that of the "Captain," though a larger ship, and though having 4 feet more beam, she had very little, if more, stability at equal angles of heel up to 14°.

It is most inaccurate to estimate in a general argument the statical stability lost by a low freeboard, without setting off the antecedent advantage of lowering the centre of gravity by dispensing with so much side, and its consequent great weight of armour; this an architect must provide for by building a larger ship, which was done in the case of the "Monarch," so these ships are not fairly comparable.

The loss of buoyancy and of stability, however, was exaggerated, for it will be seen from Fig. 2, plate II, that though the gunwale is immersed, that to effect this the bottom of the ship at that side or bilge must be further immersed. Now it is there that the buoyant pressure is, and there is no diminution of it consequent upon the loss above, and this pressure below increases more and more as the gunwale is immersed, and the stability is increased with it, for the greater the immersion of the bottom, the greater is its moment of buoyancy on the supporting side of the ship up to certain limits, while the immersion of the upper part of itself adds little or nothing to the buoyancy, as the pressure on it is nearly all lateral, whether the water be shut out by a side or let in by no side; the only deduction, therefore, to be made for a low gunwale is the weight of water admitted, multiplied by the horizontal distance of its mean centre from the general centre of gravity which, unless the gunwale is very much immersed, will be nothing in comparison to the increased moments of buoyancy arising from the deeper immersion of the bilge. The danger and loss were from other causes, which I have already described, and which commenced before the gunwale came down to the water.

Any freeboard is a departure from the stage principle, and so far injurious to the ease obtained by the stage; but while the low freeboard admits the sea and is perpetually wet in bad weather, it admits of the centre of gravity being in a better position for stability, all other things being equal, and if a sea breaks on board of her, it has an immediate exit. On the other hand, the high freeboard excludes the sea and its weight, but it necessitates a high position for the centre of gravity, particularly in an ironclad, and a consequent reduction of stability. She will heel, therefore, more, and if a sea breaks over her high freeboard, it will confine it on her deck, and she will be like our old deep-waisted vessels that had to burst their side and stern ports out to prevent their foundering from the weight of the sea breaking on board.

Almost in the same breath the "Captain" was said to have capsized by her sails, and yet that without any sail, if she encountered waves of her own period she would roll violently, and might be in danger, of

course, of rolling over. No doubt with so little stability, it would have been difficult for the best sailor ever known to have kept her on her legs, for practically she had no sea legs, but as the "improvement" projected for the "Invincible" was carried in the "Captain" to the point of perfection, it is strange to be told she would have rolled at all, much less violently.

It has appeared a difficulty to some that the "Captain" should have stood up under a press of sail on the day before and day she was lost, and yet on the evening of the same day have gone over so easily, and so much under a less press of sail.

The explanation is simple. When under a crowd of sail the water was tolerably smooth, she was going fast, and not making much leeway; as the sea and wind increased, the sail was reduced, from both causes the headway was reduced and the leeway increased.

Owing to the good form of the "Captain's" forebody the direct resistance resolved would give a large vertical thrust, which would have given her considerable dynamic stability, and the faster she went, the greater as the squares of the velocities.

Going fast, her leeway would be, say half a mile an hour, the pressure from a small immersion of bilge from less inclination and less drift, the tripping pressure would be only about 100 horse-power. When her headway was reduced, she would incline more, immerse her bilge more, and drift faster, say two miles an hour, then the tripping force would be increased to 1,200 horse-power, increasing with the drift and inclination to an indefinite amount, making a tripping force of 6,000 horse-power, greater than would have been, had the ship been built as designed.

The question still arises, what ought to be the amount of stability? The statical stability should be in excess of the moment of sail, but also of the moments of lateral pressure of the water on the lee side, and of the wind upon the hull above; and further, the estimates founded on these should be corrected by experience.

The "Conqueror," a powerful 90-gun ship, having taken out her main guns to accommodate 500 Marines whom she was taking to Japan, fell in with a cyclone, and though at her load-draught heeled from 40 to 45°, and finally was blown over on her beam-ends, without a stitch of sail being set, and her topgallant masts down as far the topsail yards. The sea was level, therefore her heel was from the continuous force of the wind.

The height of her meta-centre above her centre of gravity was 4·589 feet, her length 218, her low weights and comparative light upper works saved her from going over and turning bottom up. The calm centre passed over her; relieved from pressure, she righted a little, and they helped her to get on her legs before the other half of the storm came on. Can anyone doubt that had any one of very many of our ironclads been there, they would have been blown over much before the "Conqueror," seeing that their lengths vary from 270 to 400 feet, and their heights of meta-centre vary from only 3·3 to 2·3 loaded, and 1·5 to 2 when light. For though some of these ironclads possess great moments of inertia from their armour, and do not roll much

ordinarily, yet they have little inertia from the distribution of vertical weights as compared with her; and the inertia of lateral weights cannot be made to do duty either for a deficiency of statical stability or for a due amount of inertia from vertical weights, for the action of the power of the former is only that of preventing the vessel from being forced quickly into motion by a passing wave, but it is no matter how great the inertia may be, a continuous pressure of wind will incline a ship,—deficient in the other stabilities,—and finally would blow her over. This may be said to be an unusual case as to strength of wind, but much less wind, the sea concurring, would produce the same results; and how much sooner would this condition occur in ironclads with so much less initial stability, and with other conditions most unfavourable to stability, with this further fatal objection to the latter, that once over, they must go down and drown their crews.

I ask, can such be deemed in any true sense sea-going cruizers?

But the "Conqueror" was in one of the worst positions a ship could be in, viz., without way, and therefore without dynamic stability—a condition not understood by architects, who give ships so little initial stability—subject to the whole force of the wind on the side above the centre of gravity, driving her to leeward and turning her over with all, and all the force of the water on her leeside resisting being driven to leeward, a force not exerted at or in a line with the centre of gravity of displacement, but much lower down and very many feet below the centre of gravity; how could an ironclad with a high centre of gravity a deep immersing bilge, and a light bottom without inertia seeking to float up, escape capsizing?

Moreover, it is more than probable that any old wooden two-decker or a heavy frigate that should run aboard on the beam of one of these ironclads with so little initial stability, hitting her above the centre of gravity, would turn her over.

It is clear then, that ironclads especially should be given a sufficiency of initial stability to give a reasonable assurance that they will not be thrown on their beam-ends by wind or sea, or by both together, or be rolled over by concussion. It is clear from the "Conqueror's" case that this cannot be obtained with a less distance between the meta-centre and centre of gravity than 6 feet.

The metacentric height of French ironclads are 4 feet, 5 feet, 6 feet, and even 7 feet, amongst which is the "Solferino," a two-decked armour-clad ship, and she is said to be the easiest. All are said to be easier than the unarmoured ships, but what is more important, they are safe as compared with ours. The secret of the easiness of the "Solferino" is the great moments of her vertical weights.

It becomes a question whether some means should not be taken for giving ironclads increased buoyancy above to give the crew time to escape with their lives, and also to give a chance of saving the ship.

It has been said that I am opposed to double bottoms; this is not the case. I object simply to the empty double bottom arrangement without compensation. I object to raising the weights 3 or 4 feet off the bottom, and so raising the centre of gravity. If this has been found necessary in iron bottoms, better return to wooden bottoms, as

the uncompensated raised floors lead to drowning the crew and the loss of the ship.

It is affirmed that this arrangement, or at least the deep frames, are necessary for the strength of the ship. Now this I deny; the true principle is to put the strength at the top, put as much as is necessary below, and the rest of the available cellular space should be above. This would give buoyancy in the event of a vessel being thrown on her beam ends, and give her a chance of righting or being righted, as in the case of "Conqueror," instead of turning bottom up, as a high centre of gravity and a large empty space below will occasion.

It is high time to consider the subject of making vessels more or less unsinkable as proposed by Mr. Drake, long since, and perhaps by a better plan, that of Mr. Renton. There can be no doubt but that in proportion as ships were made unsinkable, much of the heavy armour might be safely and wisely dispensed with.

I hope to have made it clear that many of our ironclads are dangerously deficient in stability, and that the plea for giving them so little is without the least foundation, and that this quality is over-estimated in all ships, and that means should immediately be taken to ascertain their actual stabilities, that this cannot be effected by the ordinary method, nor can such calculations as those hitherto made be relied on, nor without the actual forces ships are subject to being taken into consideration under the most unfavourable circumstances.

For the first, the actual pressures on ship's bottoms must be determined. It can no longer be tolerated that these pressures shall be assumed to be collected where it is impossible that they can be, or that the buoyant forces of all immersed parts of all ships are alike in each ship, and alike in all ships whatever may be the distribution of their weights.

The actual pressures on ships' bottoms as determined, must be resolved into vertical, lateral, and horizontal pressures, and the vertical collected into vertical planes referred to a middle plane, having its genesis in the outer skin of the ship; this should be determined accurately for each angle of inclination, and not in the crude way that they now are.

For the second, Naval Officers must be called into council. The Navy never can again be left to architects alone, not even to the Controller's Department. We have been continually victimized by this narrowness, a hobby always being ridden to the great injury of the Navy, and at a senseless cost to the country; the extravagant and dangerous things that have been done by them no sailor would have been a party to. There is a large field outside the immediate province of the naval architect and the shipbuilder, which can be occupied with advantage and safety only by the sailor; he only can study ships in their element, he only knows the ships of fact, not of fancy; in truth he only can possess the double qualification that makes a complete architect. This it is that makes Admiral Chapman so great an authority.

Till sailors are accorded their proper place, there will not be progress, ecomony, or efficiency. If they are supplied with the neces-

sary information, they will take increased interest in their ships and their performances; and in one cruize they would obtain accurate information from the intelligent experiments they would then be enabled to make, that would be worth more than can be collected now in a hundred.

If an intelligent observer of the chopping and changing, building, pulling down and rebuilding, masting, unmasting, and remasting in another form, and other interminable changes, were asked what impression was made on his mind as to the science of naval architecture, as illustrated in our dockyards, he could but say it was most characterized by a want of common sense, and by a want of definite knowledge of the subject.

To my young brother Officers I say, do not imagine that naval architecture is a subject that is beyond your abilities, and too abstruse for you to study with success; believe me it appears nearly as abstruse to the naval architects, for the subject is little better understood by them than you; you know much that they do not, and much of that which some of them profess to know, they as little understand as you do. Mistiness often passes for profundity. The contradictions of themselves and of each other is quite marvellous in that which is supposed to be a science. All that the architect really knows, that is necessary for you to know, you can acquire in a very short time; you need not trouble yourself with transcendental mathematics, your common sense and knowledge can easily be translated into such, but much of such mathematics, as applied to ships and some other things, is untranslatable into common sense.

The system under which officers have been kept ignorant of everything worth knowing concerning their ships and the fleet, can no longer be tolerated; it is injurious to the public service, it is unjust to the officers and men whose lives are imperiled by it, and who have a right to be consulted as to that which concerns their honour and their lives; none can know so well what is best suited for the particular service he has to perform, and none has a greater right to judge than he who is responsible for the service and for the lives of his crew, as the Naval Officer.

Vice-Admiral Halsted: Mr. Chairman, with your permission I will make a motion which, no doubt, will be deemed necessary by the whole of this assembly. I know that we shall all acclaim the vote of thanks that will be given to the lecturer. But what I wish to say is, that it is simply impossible that this question can be discussed to-night, nor can it be discussed, really and practically, until we have had an opportunity of reading the paper for ourselves in such a form as to enable us sufficiently to comprehend it in detail. The very fact that there is so large an assemblage present gives proof of a heartfelt demand for a thorough consideration of the question on the part of every class of the community, quite apart from the Navy itself. It ought to be discussed very deeply, closely, calmly, and deliberately, and unless this Institution does really and truly afford every means and facility for doing so, it were better that the paper had been read elsewhere. I do not mean to say that those facilities will not be given, but I wish to lay stress upon the fact that this Institution for its own honour's sake, should give every reasonable facility and opportunity for discussing a paper of such vital importance. If I may be permitted just to forestall any further remark with regard to the paper, the facts and circumstances of the terrible catastrophe which have produced this paper, have all occurred through the means and the

application of sail, yet there has not been a single reference made public as to what sails were used or what sails were supplied in the case of the poor "Captain" which went down, or in the case of the "Monarch," which did not go down. Therefore, if it be felt desirable, on the part of the Institution and of the assembly, that we should arrange for the future discussion of this paper, I would suggest that the Institution should make application to the Admiralty to have the sail-plans of the "Captain," "Monarch," and "Audacious" supplied to us.

The motion having been seconded, the meeting was then adjourned to Monday, the 23rd instant.

Monday Evening, January 23rd, 1871.

Admiral of the Fleet Sir GEORGE ROSE SARTORIUS, K.C.B., in the Chair.

ADJOURNED DISCUSSION.

After a statement on the subject of the sail-plans, the Chairman called on Admiral Halsted to commence the adjourned discussion.

Vice-Admiral HALSTED: In obedience to the call which is made upon me, and in the position I placed myself in (but which I was not cognizant of when I made the motion for the adjournment of this discussion), I, of course, accept the consequences, although I was not conscious of what they would be, and I would far rather that the opening of the discussion should have devolved upon more able parties than myself. We have had ships of which our Chairman has possibly had more experience than I have—many classes of ships, performing very valuable duties and services in the Navy, which we characteristically and rightly termed "coffins." But the coffin characteristic of those ships was a thing perfectly known, before any of us, man or boy, stepped foot on board of them. We knew very well where their coffinage, so to speak, occurred. We knew the circumstances under which we were likely to be so coffined. And we knew that it depended upon external circumstances, the state of the weather, and our own management of those ships. We all knew the liability to danger when we embarked in them, and we, therefore, were prepared to take every rational precaution for the safety of the property, and, above all, for the safety of the lives of everybody on board. But the question which we are now called upon to discuss is one entirely distinct from any such well-known conditions of danger. I do not hesitate to say, that no person of whatever rank embarked in the "Captain," no person, of whatever rank, who had charge of the sail trials and other general trials—I am speaking now of the senior Officers having charge of the single ship, or ships, or squadron of ships, of which the "Captain" formed part—were at all conscious that there was a latent source of absolute danger, perfectly defined, beyond which limit the risk of absolute destruction to the ship and those who were on board her, was involved. Now the loss of the "Captain" acquires its grave importance, not from the actual terrible catastrophe to the "Captain" herself, but as an exemplification of what must occur in my opinion to even more of our ironclads than those which have been mentioned by Admiral Fishbourne. It is perfectly certain, and without mistake, that the same result may, and must occur, unless preventive means be employed which were not employed in the case of the "Captain." It must occur with the whole of that class of ships, of which the "Audacious" is the exemplar. My views on this matter were much altered and modified by the arguments used, and the statements made by the lecturer. I had attributed the loss of the "Captain" largely, and perhaps even now it is partially to be attributed to her low free-board. But what I see plainly before me in the case of the "Invincible," the first of that class of ships, is a result of similar or even greater instability; for without sails, with

merely the wind upon the beam, and the gallant-masts upon deck, she showed an inclination of 17 degrees. I say then, that I am right in speaking of the loss of the "Captain" as being a mere example of what may occur in seven other different ships, six of them forming one class, for every one of those six ships are exactly similar to the "Invincible" in all their conditions and equipments. And since then, there has been added the means of safety to the seventh ship, the "Sultan," a ship as large or larger than the "Hercules." It has been found by a re-examination of her stability, or elements of stability, that it is necessary to employ the same means with regard to her. The "Sultan" will go forth as a mere tentative experiment, not with regard to her speed, not with regard to her power of turning, not with regard to her powers under steam, but with regard to actual safety for life as involved in that word "stability."

Now the area of plain-sail in the "Monarch" is 27,700 square feet, that is, in the courses, top-sails, gallant-sails, jib, and spanker. This area of plain-sail has here alone been estimated, as it represents the motive-power *versus* the "direct resistance," measured by the area of the ships's mid-section at load-draft. That of the "Captain" is 27,574 square feet. The centre of effort of these areas above the centre of lateral resistance is 91 feet in the case of the "Monarch," 94 feet in the "Captain." The centre of effort afore the centre of lateral resistance is 13·2 feet in the "Monarch;" 23·1 feet in the "Captain." There is therefore a difference of 10 feet practically in the position of the centre of effort between those two ships, which do not at all differ in their respective lengths in that degree. One or other of these therefore must be wrong. The area of mid-section at intended load-draft is 1,224 square feet in the "Monarch," 1,078 square feet in the "Captain," therefore the area of plain-sail per square foot of mid-ship section, which is the accepted mode of measuring the proportion of power to direct resistance, is, in the "Monarch," 22·6 square feet; in the "Captain," 25·5 square feet.

Now the proportion of Plain-sail in sailing days for our 50-gun frigates of, say, 2,400 tons, and that is going to the largest of them, was 36 square feet per foot of section; and for this they were provided with safe and ample stability. The proportion, therefore, in the above two ships is thus, roundly, one-third too little to have constituted them true sailing ships at all; and for this the stability provided was so defective as to be fatal to the "Captain." Her loss, therefore, cannot be imputed to excess of sail-power (and I lay great stress upon that important point), but to the dangerous defect of stability for enabling her to use the largely reduced sail-power she had. And this danger had a perfectly defined and ascertainable danger-point, to which I will speak presently. The mean proportion of sail-power throughout our present iron-clads may be taken roundly at 24 square feet of plain-sail, per square foot of mid-section, a power quite insufficient, by all past experience, to enable them, whatever their stability, to perform with safety and certainty any emergent sail duties if disabled in steam power. But our ironclad frigates may be taken, roundly, at twice the tonnage of our former wooden fifties, and as larger ships can bear, or should bear, larger sail-power than smaller ones, there is indication that the practical art of providing our Navy with sail-power, safe or unsafe, is already less a reality than a pretence.

Of all the ironclads which have been inclined, the "Achilles" has been more completely so than any other. The "Achilles," as stated by our lecturer, is in all main elements of her construction the same as the "Warrior" and the "Black Prince." She was built off the very same lines, the very same drawings, but with this exception, it was considered desirable, so far as it was possible, to complete her armour protection beyond the limited protection given in her two sisters, and that intention was carried out thus:—She was sunk one foot deeper into the water, giving that increased amount of displacement, and bringing her port sills from 9 feet 6 inches to only 8 feet 6 inches out of water. Her bottom was also, as was rightly stated the other day, filled out, with which additions to her displacement, she was made to carry the prolongation of her armour right forward and right aft as she now is up to the platform of the main deck, no higher, and then the effect of adding this armour weight above, and this increased buoyancy below, was put to the proof by inclining the ship both when she was light

and when she was loaded. The paper written by the Officer of the Admiralty who made that experiment formed the subject of a very valuable paper read at the Institution of Naval Architects in 1864. However, here we have a case in which one of our ironclads, as indeed the greater part of them, has been put under this experiment of inclining, as an essential process towards realising and measuring their safety from danger; that is, as I have already specified, determining their danger-point, and it was in absolute furtherance of that purpose that when the "Captain" herself was sent round from Birkenhead to Portsmouth there came with her, or immediately following her arrival, a letter from the builders, requesting that as all the former peculiar ships had been inclined for the purpose of ascertaining absolutely by a physical mechanical proof, like weighing a leg of mutton in the steelyards, quite irrespective of calculations, correct or incorrect, so that same experiment might be performed with the "Captain," also that they might ascertain the result as affecting her stability and safety. Such was their request when they sent round that ship to be completed in her weights, and the basis of their application was as I say.

That was not done, as we all so painfully know. That which was applied for on the 24th of February, approved of and recognized as necessary on the 26th of February, was not performed until the 29th of July. The data then procured were not worked out until the 23rd of August following. On the 4th of August the Fleet, including the "Captain" and the "Monarch," had proceeded to sea. The "Captain" was not detained to communicate the result, although the experiment itself had been made, and the working out the results derived from it in order to ascertain what I call the "danger-point" was then still in process—but she went to sea. From the 25th of August till the 1st September the "Captain" with the other ships was in Vigo Bay, and therefore those in command of her were perfectly capable of being informed as to what the ascertained result was. Now what was that result? The result was to shew that at an angle of 21 degrees of inclination the ship had arrived at her maximum amount of stability. When that was read before the Court-martial, the President expressed his grave surprise, and requested to know whether such information was or was not communicated to the Commander-in-Chief having charge of the trials, or to either Captain Coles or Captain Burgoyne, but it was not so.

Now, at the Court-martial it was stated by the Officer who had first the superior charge of the trials of the "Captain," that had he been made acquainted with that danger-point, as put forth here, not one stitch of canvas should ever have been carried by that ship during night. That is the practical result of what I am speaking of.

Again, we find the latest Commander-in-Chief of the squadron in which the ship was, talking with Captain Coles and Captain Burgoyne, questioning the circumstance of the ship being then inclined 13½ degrees with the water upon her upper deck, as to whether there was or was not danger to her in that position. The crucial question put by Captain Commerell at the Court-martial, to the Officer who made that experiment, was "Under the circumstance of your having made this experiment, what, in your opinion, was the extreme inclination to which that ship could with safety have been inclined?" "From 15 to 16 degrees," was the answer.

Now I ask if that communication had been made to Sir Alexander Milne, and to the Officers on board that ship, would they have been discussing whether there was or was not danger, some twelve hours before the actual capsizing of the ship, in an incline which then existed, with the ship under royals, of over 13½ degrees, or within 1½ degrees of the danger-point then ascertained?

I may be very wrong, and I have been very slow, no doubt, in bringing out this question of the danger-point, but there is a danger-point, and that danger-point was known, and it was not communicated, and to that I attribute the immediate, the direct, and the preventible cause of the loss of the "Captain." Let those who can—I cannot—discuss the far remoter cause of why the ship was lost from having that danger latent within her. I will not pretend to enter into that question.

Mr. Charles Henwood, Naval Architect: Admiral Fishbourne said, "I may state there are three kinds of "stability." Now I think it is much better—as I have

been taught, and have always practised—to divide stability under two heads, that is, hydrostatical and hydro-dynamical. Professor Mosely has, it is true, introduced what he terms dynamical stability; but inasmuch as such stability could have no existence in a perfect ship—if such were practicable—we may disregard it on the present occasion. The following tabulated particulars of the "Warrior," "Achilles," "Prince Consort," "Minotaur," "Orion," and "Conqueror," will illustrate this question of stability:—

	G. M.	G. Z. at 10°.	Displacement.	Moment of Stability at 10°.
Warrior	4·68	·81	9035	7318
Achilles	3·09	·54	9484	5124
Minotaur............	3·88	·67	10311	6938
Prince Consort	6·01	1·04	6696	6963
Orion	6·12	1·06	5101	5407
Conqueror	4·59	·78	5777	4506

In the "Warrior," you see the meta-centric height is much greater than in the "Achilles;" the displacement in the "Achilles" is, however, larger than in the "Warrior," and therefore, according to Admiral Fishbourne, the "Achilles" has greater stability of immobility, and this is the reason why the "Achilles" is steadier than the "Warrior." But, on the other hand, I maintain it is comprised in the question of hydro-dynamical stability, that is, in the disposition of the weights, for the weights and submerged solids of the "Achilles" are very differently disposed to what they are in the "Warrior."

Again, take the cases of the "Minotaur" and "Prince Consort." You will observe that they have about the same hydrostatical stability at 10 degrees of inclination; the "Minotaur," as is well known, is one of the steadiest of our ironclads. This fact, according to Admiral Fishbourne, would be attributed to her larger mass—her stability of immobility. On the other hand, I maintain it is attributable to her possessing greater hydro-dynamical stability. It is quite true that, *cæteris paribus*, the larger the mass, the greater the immobility, but in the case of a ship, she may be so badly designed that, although a large mass, her immobility may be very small. Take, for example, the "Prince Consort," of 6,696 tons; she is about one of the worst rollers in the Navy; the "Orion," on the contrary, of 5,101 tons, is reported to behave well at sea, and many of our wooden frigates, of not more than one-half the "mass," are much steadier than the "Prince Consort," the fact being that although the hydrostatical stability of the "Prince Consort" is comparatively great, her hydrodynamical stability is very small, hence she is not a steady ship. The "Orion" and "Conqueror" being similar ships, their comparative steadiness would depend on their disposition of weights and submerged solids, that is, hydro-dynamical stability. There is as much evil in too great a concentration of weights, as in too great an extension of them; and the errors involved in either case can only be obviated by following the dynamical system of construction propounded by my father, more than thirty years since. That system may be briefly stated as follows, viz., that *the moments of inertia, of the weights about the centre of gravity, whether vertical, transverse, or longitudinal, shall be equal, as well as those of the submerged solids, and the moments of inertia of the submerged solids shall not be less respectively than the moments of inertia of the weights. Also that the longitudinal stability of the fore submerged solid shall not be less than that of the after submerged solid.* This important problem appears either not to have been comprehended, or else ignored

by the Controller's department, especially in the latest designs. The examples mentioned by Admiral Fishbourne illustrate this fact. I must refer here to one or two papers, written by Mr. Reed. In "Our Ironclad Ships," pages 46 and 47, he thus propounds a dogma, asserting that "a high position of centre of gravity tends to produce steadiness, and a low position tends to cause excessive rolling." The same fallacy is also enunciated by Mr. Robinson, the master shipwright and engineer of Portsmouth Dockyard. It will be found at page 279 of Mr. Childers' minute. Mr. Robinson there asserts that, "it is a well known fact that the lower the centre "of gravity is placed in a ship with respect to the meta-centre, the greater will be "her tendency to roll; and, as a consequence of this, it must be remembered the "more unsteady will become her platform. The only way to obtain that essential "quality of a good fighting ship, namely, steadiness of platform, is to give her as little "stability as possible, by means of bringing the centre of gravity and the meta-centre "as near together as is consistent with keeping sufficient stability to make her sea-"worthy." These dogmas, as abstract principles, I entirely deny, and what are the facts? Why the centre of gravity of the "Monarch" is 12 inches below the load water line; that of the "Captain" was 35 inches, and the "Captain" was a steadier vessel than the "Monarch." Again the American monitors have low centres of gravity, as is well known, and high meta-centres, yet they are the most steady ships we know of. In my paper, read here on the 5th April, 1869, I made the following statement in relation to this matter:—"The six vessels of the 'Invin-"'cible' class and the 'Sultan," in respect to the enormous weight of their upper "deck sponson batteries, will be very heavy rollers, and this defect in seven new "vessels, involving an outlay of over £2,000,000, can only be regarded as a very "serious error." What is the answer, or, I may say, what is the opposite opinion to that which was founded on well known mechanical laws? Mr. Reed, in his book, at page 147, says:—"These vessels have, as before stated, armoured upper deck "batteries, the weight of which, being carried at such a height above water, has been "said, not only by unprofessional writers and speakers, but by professed naval "architects, to be conducive to rolling. The probability, amounting almost to cer-"tainty, is, however, that these upper deck batteries alone would make the ship "steadier, as they bring up the centre of gravity; although, on the other hand, the "great sail power of these ships, necessitating as it does a considerable amount of "stability, has put a limit to this improvement." As a matter of fact, had they not required to carry any sail at all, and had this improvement not been limited, they would simply have rolled over and over. Admiral Fishbourne has truly said that the easiest correction for this error is ballast, and it certainly is the readiest. But properly designed ships need no ballast; it is a blunder to have to carry ballast, and an expensive blunder, too.

The great depth of the frames or double bottom, is, without doubt, a very serious element of danger. In a statical sense, it is true it is comprised in the calculations of the centre of gravity of displacement and of weights, but not in a dynamical sense, and that is the more proper way to regard it. Admiral Fishbourne well illustrates this, where he takes the case of a ship without any weight to her sides, top, or bottom, and supposes all the weights concentrated at the centre of gravity; in such a case, although all the weights and displacement would be comprised in the statical problem, when you come to the question of weights in motion, those calculations are of no use whatever.

Admiral Fishbourne says,—"In the process of accommodating herself to the wave, "a ship will be the more readily and extensively inclined, as her breadth is greater, "because of the greater leverage of the half breadth." This is perfectly true, but then we must also remember that the greater breadth would give the greater stability for resisting inclination.

With respect to the direction of buoyancy, Admiral Fishbourne, if I recollect right, said some eminent mathematician had an objection to the manner in which he had indicated it. I do not think that Admiral Fishbourne is correct, and if he reflects, he will see that when a vessel is on the slope of a wave, there is not the same pressure on both sides, and it would not be correct to draw that ship with an equal amount of freeboard on each side. The action of gravity will depress

the lower side in coming down the slope, and if it were possible to draw in a correct line, then I believe the action of buoyancy should be indicated perpendicular to the plane of flotation.

I quite agree with Admiral Fishbourne, that "a ship is in no wise like a free pendulum." Ships may be moved about as I have seen them on rolling waves, without their plane of flotation being disturbed. That we may term relative motion, or the motion of translation, the wave moves the ship from one place to another; but the ship itself, about her centre of gravity, need not necessarily move if there be no wind. Then the two motions may be combined, the motion of the ship about her centre of gravity, and the motion of translation. But neither in the one case nor in the other, nor in both combined, can a ship be likened to the action of a free pendulum. I now come more directly to the question of the loss of the "Captain," though all these points tend to that question, they are all in the paper, and indirectly connected with the "Captain." In concluding my remarks on this part of the paper, I would only say I think no one would imagine that naval architecture is a study beyond the abilities or too abstruse for the study of the sailor*; but the old saying still holds good, that "a jack of all trades is master of none." The naval architect should derive assistance from the sailor, and the sailor from the naval architect. Each profession embraces a field of its own, at once so large and special, that those who may seek to acquire mastery and proficiency in both, will inevitably fail, and acquire proficiency in neither.

With regard to Captain Coles' responsibility, I maintain that he ably and well fulfilled what he had undertaken to do, as shown by the reports of Admiral Sir Thomas Symonds, particularly in that the "Captain" was *always ready for action*, while the "Monarch" *required an hour and a half to prepare.* I may mention, that having been consulted professionally by Captain Coles on many occasions prior to the building of the "Captain," I am well acquainted with the amount of theoretical knowledge he possessed, and I say sincerely that he never to my knowledge discredited or disregarded well-ascertained theoretical facts; and although he had good reasons for ignoring the mere *ipse dixit* of opponents, I am convinced he would have paid due attention to any proper official communication. Admiral Fishbourne refers to the different meta-centric heights as indicative of stability; but meta-centric heights are only of use for ships of the same type and character—for instance, as in the case of our old line-of-battle ships, our frigates, or corvettes; but for ships differing in construction, mere meta-centric height does not afford any real comparison of what a ship should be. I must just refer here to the "curve of stability," as it is called. I have no doubt many gentlemen have seen it alluded to in the First Lord's minute. This so-called "curve of stability" is not a curve of stability at all. It does not represent stability; it is merely a curve that represents the angle at which the maximum stability is arrived at, but it does not at all give you any indication of what the stability of the ship is. Therefore, to call it the "curve of stability," is a misnomer; it should be called merely the "curve of the levers;" it is only half of a mathematical problem, and cannot give information to any one beyond indicating the angle of maximum stability, not even to a naval architect. To arrive at what the stability is, you must find the weight of the ship, and multiply it by the length of the lever at any angle; for instance, take the angle

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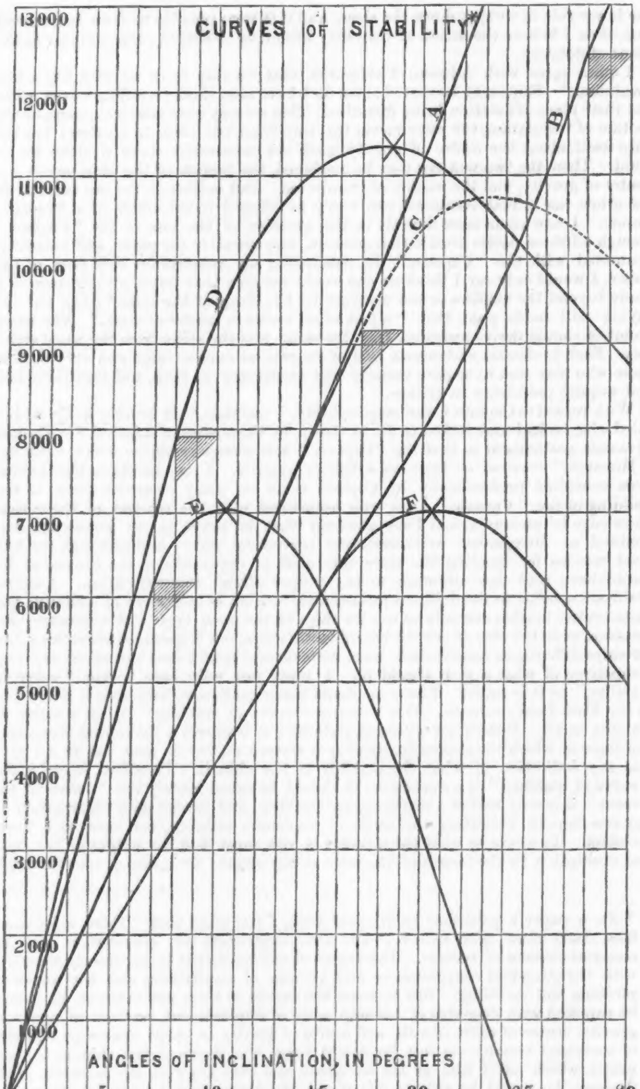
* In a paper I published in the year 1865, I remarked that "there exist more "false facts than false theories, and that correctness of observation was an "essential element of success. The angles of rolling should be accurately recorded, "with the attendant circumstances and periods of oscillations, also the angles of "pitching and 'scending. But to assist the sailors in these observations, he should "be supplied with diagrams of his ship, scale of displacement, position of centre of "gravity, centre of effort of sails, and centre of gravity of cargo spaces (in the case "of merchant vessels)—in fact, he should know the *design* of the ship, as to those 'points which affect him as the navigator, and thus knowing the intention of the 'designer, he would be able to follow out the design, and by careful observation 'afford data for investigation and future application."



* The hydrostatical stability of A and C, "Achilles" and "Captain," as designed,

of 10°; you then by the scale on the left hand obtain the length of the ordinate or lever, and multiply that by the weight of the ship, and then you get the stability of the ship at that angle. I have taken the diagram on page 43 of the minute, and multiplied the length of the lever at the various angles by the weight of the ship. So we have here the actual "curve of stability" of "Captain" as received;(F) but I wish to impress upon you that the *danger-point* is the maximum "moment of stability." That point once reached, the opposing forces still continuing, she must go over. The diagrams prepared by the Admiralty Constructors, only give the extent of stability; they do not give you the measure. In this diagram you have the measure and also the extent. In the "Captain" as received, the measure of maximum stability is 7007; the extent is 20°, or 21° assuming that the poop and forecastle really are of any practical value, which I doubt. The Controller in his report after the loss of the "Captain" speaks of such calculations as "now made for the first time," whereas the fact was, that the "curve of levers" had been drawn for a similar type of ship three years previously. Mr. Barnaby, in his evidence before the court-martial, says, "I was myself the first person to point out the *element of danger* "introduced by putting sail upon such ships. I prepared the first investigation "made for the purpose of ascertaining its amount, and on the 7th September "1867, these first calculations were completed. They were not made with any "reference to the "Captain," they were made by me in preparing an answer to a pro-"posal made to cut down the two-decked ships, and put turrets in them and mast "them. The freeboard proposed for those ships was 3 feet 6 inches, at least that was "an estimated height of freeboard (by Mr. Barnaby) and in that report I said, "having the 'Captain' in view, This element of danger requires to be borne "carefully in mind in all turret ships carrying sail." Mr. Reed also reports on this same subject, and it was a very important subject, because it concerned property of the value of over eight millions, and they expended a great deal of time and attention in enquiring into it. And it is not a subject that we must disregard on the present occasion, for it will be of great advantage to those interested in the subject matter of this paper. He reports, at page 118 of Mr. Childers' Minutes, "The line AA represents the stability of the ship at various angles, presuming the centre of gravity to be situated, *as it would be if the ship were made a Henwood monitor*, but with the sides carried up as in an ordinary ship. The curve line A C shows the same thing for the "Duncan," as a Henwood monitor. That is with 3 feet 6 inches freeboard, and the centre of gravity situated as it would be if the ship were a Henwood monitor." I want particularly to show you where, in Mr. Reed's opinion, on that occasion the centre of gravity would be. He says (page 309 of the Minute) "in the "Duncan,' with 3 feet 6 inches freeboard, the centre of gravity was estimated to be $\frac{2}{10}$ths of a foot below the load-water line." Thus you will see the centre of gravity was assumed to be $\frac{2}{10}$ths below, although I had, in my letter to the Admiralty, three months previously (page 115), shown that it would be at least 18 inches below a water line giving 4 feet $3\frac{1}{2}$ inches freeboard. In the "Captain," a similar type of ship, it was 35 inches, and Mr. Reed admitted, in the discussion which followed his paper, that "it would be a matter of calculation to ascertain exactly to what extent you would lower it," and subsequently in his book on "Our Ironclad Ships," at page 137, he makes this remark, and this is very important for Naval Officers to know:—"Comparing an ironclad with a line-of-battle ship, we find the former with less lofty sides, and with a single gun-deck, so that,

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are equal up to an inclination of 14 degrees. Also that of B and F, "Monarch" and "Captain," as received to about 15 degrees; and taking the edge of the deck in all cases as practically the maximum moment of stability, that of the

A "Achilles"	equals	....	18600
B "Monarch"	"	....	12452
C "Captain" as designed	"	....	9150
D "Duncan," converted	"	....	7900
E Assumed ship	"	....	6150
F "Captain" as received	"	....	5600

although the sides are covered with armour, the weights, as a whole, are not so high out of water. For the sake of illustrating this point more fully, I will take the case of a converted ironclad, say of the "Caledonia" class, the two-decked wooden ships which were turned into armoured frigates, had their sides cut down considerably, and the main deck and its battery removed, while the armour, although about equal in weight to the parts removed, is not as high above water. The ironclad is, therefore, less topheavy than the wooden ship was, previously to being converted; in other words *the conversion* has *the effect of bringing down* the centre of gravity of the ship. The truth of this has been confirmed by actual experiment, and calculations for several converted ships." Yet, for the purpose of this diagram, and reports on pages 118 and 119, which actually capsized my proposals to the Admiralty, the centre of gravity was assumed to be 18 inches *higher* than in the wooden line-of-battle ships previously to being converted, and more than 2 feet higher than in ironclads of the Caledonia class. I will, however, confine myself to these diagrams, and as the Chairman desires me to be brief, I beg you to accept them as correct, for I am prepared at any time to prove their correctness by documentary evidence. On the diagram is shewn the "curve of stability" of this "assumed ship," E, viz., "Duncan," with 3 feet 6 inches freeboard, and centre of gravity 2 inches below the water line. Mr. Childers mentions that was rejected by the Controller's Department on the ground of instability, being dangerously deficient in stability, and quite unfit to carry canvas. The stability of this assumed ship, when the edge of the deck would be immersed in the water, would be 6150, the maximum moment of stability 7027, and the moment of all plain sail 1024. These were the "alarming results" referred to in the Controller's report (page 117 of the Minute) which required "to be borne carefully in mind in all turret-ships carrying sail." Now here is the point to which I wish to draw your special attention: when the edge of the deck of the "Captain" was immersed in the water, her stability was only 5600. A force of wind and waves that would have heeled the "Captain" until her deck was immersed in the water, viz., to 14°, would not have immersed the edge of the deck of this assumed ship, that was dangerously deficient in stability, but only have inclined her to 6½°. The maximum stability of the "Captain" was 7007, and the moment of all plain sail was 1088, therefore the "Captain," as received from the Contractors, possessed a greater element of danger than this assumed ship. I have deduced from the evidence given in the First Lord's Minute the stability of the "Captain," as designed; indicated on the diagram C, with 8 feet freeboard, and the centre of gravity 3 feet below the water line. The "curve of stability" is only calculated up to the height of the edge of the deck, and that part beyond the edge of the deck in ticked line is assumed. You will see the stability of the "Captain," as designed (taking the edge of the deck in both cases), was 9150, and there is no doubt that, as designed, the "Captain" was practically as safe as any ship in Her Majesty's Navy. But you will observe the enormous difference between the stability of the "Captain" as designed, and that of the "Captain" as received. Now, in the case of that assumed ship—merely a proposition on paper— how was it that so much more trouble was taken about her calculations, the results of which gave "the alarming results" referred to in the Controller's report, page 117 of the Minute, than was taken about those of the "Captain," a costly vessel with over 500 lives on board? And passing strange that they condemned that assumed ship, as being dangerously deficient of stability, and quite unfit to carry canvas, yet could see no cause to apprehend danger in the "Captain," possessing less stability and greater sail power.

In order that you may see that lowness of freeboard is not necessarily an element of danger, this model represents a ship, not with 8 feet of freeboard, not with 6 feet 6 inches of freeboard, but only 4 feet 3½ inches of freeboard.

The CHAIRMAN: How do you account for the "Captain" being capsized?

Mr. HENWOOD: Insufficient stability. If any competent naval architect had had the drawings and calculations before him, he would not have passed that ship.

Captain SELWYN: May I ask in which sense Mr. Henwood uses the word "stability," because there have been two meanings attached to the word. He says "deficient stability." Does the stability attach to the disinclination to be rolled, or to the inclination to roll? Does your use of the word "stability" attach to the disinclina-

tion to be removed from the vertical, or to the inclination to be constantly moved from the vertical? because, as it has been used in both senses, it would be worth while to know.

Mr. HENWOOD: The disinclination, certainly. I never knew that it was the inclination to be moved from the vertical that was termed stability. I have learned something, certainly, if it is so. (Captain SELWYN: I think I shall be able to show you that it has been so termed lately.) Again, about the question of low freeboard. The "Captain" had 6 feet 6 inches freeboard, and about the same draught of water as the "Duncan," with 4 feet 3½ inches of freeboard. Now, you can well understand; no argument from me is required to prove to you that the centre of gravity in a ship with an armour-plated side of only 4 feet 3½ inches above the water, must be lower than in a similar type of ship with an armour-plated side of 6 feet 6 inches above the water. But I have not assumed for this ship that the centre of gravity would be so low as it was in the "Captain;" in fact my calculations show that it would be from 18 inches to 2 feet below water; whereas in the "Captain" it was 3 feet in round numbers. Taking the calculation with the centre of gravity 18 inches below the water-line, the curve of stability of the "Duncan" D on the diagram represents a vessel with a low freeboard, 4 feet 3½ inches, yet possessing stability actually more than 60 per cent. greater than the "Captain," as received. This fact is a complete answer to the statement that low freeboard vessels are necessarily dangerous. There is another fact to point out. Admiral Fishbourne shows, that when heeling to 14° the bilge of the "Captain" is immersed about 2 feet, the draught of water is increased, the area of lee-way resistance is increased, and also her capsizing moments. In the converted "Duncan," owing to her rise of floor you have no increased draught of water when heeling to any probable angle. She has actually less draught of water then, than when in a perpendicular position. From the published accounts of the "Monarch," the curve of her stability is shown on the diagram B, so that when you get these diagrams before you, you can draw your own inferences, which I have not been able to do on this present occasion. I have not said all that I intended to say, but I do not know, Sir, under the ruling that you have made, that I can say anything more on the subject.

The meeting was then adjourned to Tuesday evening, January 24.

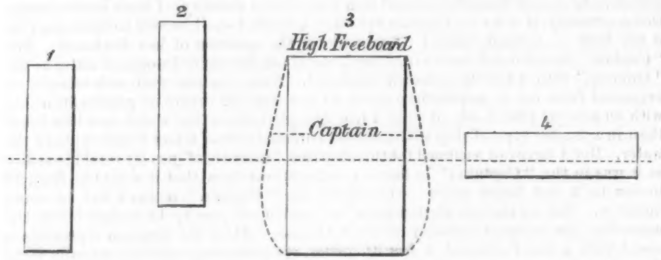
Tuesday, January 24th, 1871.

Admiral of the Fleet SIR GEORGE ROSE SARTORIUS, K.C.B., in the Chair.

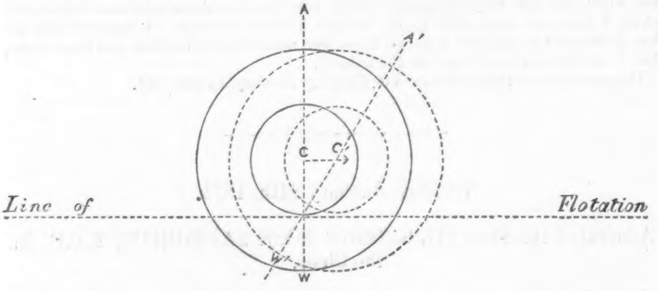
ADJOURNED DISCUSSION.

Captain JASPER SELWYN, R.N.: Sir George Sartorius and Gentlemen, it is not my purpose in discussing this question to go off either to personal questions or to those which do not strictly concern, first, the form of vessel most calculated to resist the impulses to which a vessel may be subjected at sea; secondly, the disposition of weights which may contribute to that object; and, thirdly, the forces which are adverse to stability, as it is understand by seamen, not to mean the stability of gun platform—a "*terminology*" which has only recently been introduced, and never by them, but the stability of the vessel. In doing so, I shall beg to observe that one of the first forms, and one of the most simple in which a body can float on the water is that of a cylinder: it is also the one which enables us to determine with the utmost facility the action which takes place due to the different changes in the position of the vessel. The next form which it is possible to adopt, and to which I am sorry to say a great many of our modern ships are approaching day by day, is that (Fig. 2), when you get ten times the beam, as the length; by way of getting great speed you must

necessarily approach, though I do not say absolutely reach, that form. The third form is that of the raft (Fig. 4). Between these three forms, all natures of ships may be found. Curiously enough, the extension which we see in the "Hercules" is

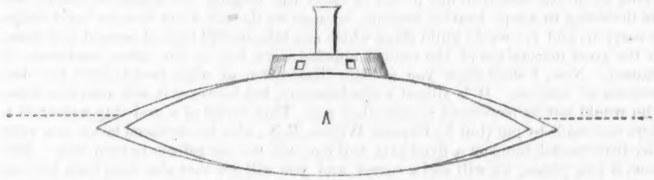


merely a compromise between the cylinder and the square, which is again an approach to the oblong (see Figs. 1 and 2). Now, if the cylinder be considered as a body floating on water, having a centre which is occupied by air, and whose inner circumference touches the plane of flotation, then it is clear that at any given moment of either inclination or roll in a given direction, the centre of that cylinder will proceed laterally. Supposing it to roll in that way, the cylinder or vessel will roll along the plane of flotation, and the changed centre will take up that position. Here C has



moved to C′, and W to W′; without unequally distributed weight at W, no downward motion of C would arise from moving A to A′. There you will remark that you have no change of the position of the centre in the sense of either raising or lowering, and you have a body which will obey any impulse communicated to it, which is perfectly indifferent as to which side is uppermost until you weight it. If we wish with that form to change these conditions—I am speaking now of the cylinder—we have only to add a very small weight at the bottom to determine the position at all times of that ship, so to call it—that cylinder. If we proceed next to consider this form—the vertical oblong—we shall find that it is also necessary to dispose of the centre of gravity, that is, to place the weights so that the larger proportion may fall below and not above. If we were to load this with a turret above, while we neglected to give a greater amount of weight below, we should immediately find that that would also capsize. But the difference between it and the cylinder would be this, that while this form will have changed the position of its centre of buoyancy when the turret is downwards and the bottom up, the cylinder would do the same thing, but it would do it without such change, unless

weighted. The raft again presents very great advantages in a certain direction. It is capable of supporting by dint of its extension over the surface, a heavy body on its upper part without materially interfering with its plane of flotation; and it very reluctantly capsizes or takes up an inverted position. It will never turn right over until it has got nearly vertical. Now, as I have said, between the form of the cylinder and the raft, are to be found all natures of vessels, being merely an adoption of more or less of one or the other. It will be clear that when our cousins across the water took up the form of the raft and added to it a bottom to enable them to put in engines, they took nearly the only form in which such a cheese-box, as a turret, could be put on such a thing as a vessel of light draught. That this is a vessel fit for the sea, neither they nor we will be probably disposed to assert. There is a form, intermediate between the two, which is the one advocated by Mr. Elder, and it does present very many advantages of the raft without very many of its inconveniences (as at A). There is the improved water line, and even with



the very heavy weight of a turret in the centre, it will not be disposed to upset. As its midship section is a segment of a sphere, you will have the greatest containing power with the least material, and you will have a very fair midship section for forcing through the water, and one to which, if you add the centre-board keel, you will have the advantage of a centre-board yacht, and you will be enabled to go to windward under sail. Now, any ignoring of the question of form will lead into the necessity for ballast. The price the naval architect pays for betraying the science he professes is, that he is compelled to adopt useless weights in the bottom of his ships. I have prepared here a model which I think will show you what is called the curve of buoyancy. The curve of buoyancy of this cylinder is clearly the inner circle, which always touches the water line, whatever position she may adopt. The curve of buoyancy of a more complicated form will also be a more complicated curve. This model, though a very rough one, will in some degree show you the adaptation of a different form to the curve of buoyancy. You will observe that in this, the vessel is not as represented in the model of the "Captain," moving on an axis, but she is moving on a certain point in a curve, which is described by naval architects as a curve of buoyancy. I trust that I have enabled you to see by means of the model, that the position of the vertical line of the ship no longer coincides as it did before with the centre of gravity. (Mr. HENWOOD: The centre of gravity of displacement, or the centre of gravity of weights.) The point of support here.

Mr. HENWOOD: That is the centre of gravity of displacement, not the centre of gravity of the ship.

Captain JASPER SELWYN: Exactly, the centre of gravity of displacement. The two lines no longer coincide. Pardon me for saying anything in the presence of a naval architect on this subject. I am speaking to those who are not naval architects.

Mr. HENWOOD: Excuse me, you said centre of gravity.

Captain SELWYN: I said the centre of gravity no longer coincides; I mean the centre of gravity of displacement. I have no doubt there are a great many persons present who know much better than myself about the whole of this affair; but there are also some few who are not quite clear as to what the curve of buoyancy means. Now, I have said that those naval architects who will not consider the whole question of form, who will not work it out under all the conditions which attach to a

problem in dynamics, and not to a problem in statics, will be obliged to come to us sailors to tell them what we want; they will find, unless they will condescend to go to sea themselves during the first four or five years of their schoolboy life, when I have no doubt they would learn a great deal, both physically, morally and intellectually—much more at least than they would learn profitably at South Kensington—if they will not do so, and if they will not accept us as sincere allies, interested beyond any gains to the extent of our lives, they will eventually have to confess their errors by putting in ballast, which is after all not a very scientific thing, since boys of all ages, old boys as well as young boys, will recollect that in their early years they cut ships of wood, and finding that they persisted in floating on their sides instead of on their keels, they put a little bit of lead on. Now that is precisely, I am sorry to say, what is the practice at the present day of some of the most scientific naval architects. In the new ships, of which mention has been made in the paper, it is confessed that they dare not go to sea without putting in weights, which if they be not useful except as weight, are decidedly injurious. We are trying by all the means in our power to carry the weights we ought to carry; we are declining to adopt heavier armour, because we do not know how to build ships to carry it, and yet we do build ships which can take in 350 tons of cement and iron, to the great delectation of the cement manfacturers, but to the utter confusion of seamen. Now, I shall show you a little illustration of what results from the disposition of weights. It is almost a charlatanism, but however it will convince some who would not be convinced in any other way. This model of a mid-ship section of a ship, not made by me (but by Captain Wilson, R.N., who has lectured here), is a very nice little model, hung on a fixed axis, and you will see she refuses to turn over. But now, if you please, we will add a turret, and you will see that she does turn keel up and you could now perambulate the keel, as we are told the gunner did as long as the poor "Captain" stayed above water. There she is, she not only persistently refuses to stop upright, but she also persistently asserts her right to stop bottom up. Now I am going to cut out the question of sail-power entirely from the discussion, as far as I am concerned. I say that the ship which cannot do, as all ships of the old sort used to do, go to sea, get on her beam ends in a hurricane, cut away her masts and right again, is not fit to be called a sea-going ship. It is useless to talk of a reserve of stability when at a certain point she will turn right over, and be it remembered I am not, as captain of the ship, told where that point is, and nobody *can* tell me when a hurricane is going to arise. We have not yet integrated that question. If I am caught in a hurricane, and my ship is thrown on her beam ends, or even past a certain easily reached inclination, she will not condescend to remain there, but will turn right over, so it is not worth talking about the question of reserves; she will go right over and drown everybody on board. We can cut away iron masts; means are known by which, with the greatest facility iron masts can be cut away. Not so easily tripod masts, there being three of them; but iron masts are not worse than wooden ones. We can relieve our ship from the weight of her sails and masts, and then she ought to right. But the failure and defect of modern ships is, that whereas all the old ships under such circumstances used to right, the modern ships won't right. It has been a fashion to raise the centre of gravity by way of making a stable gun platform. If I raise the centre of gravity to a certain point, the ship goes over altogether and suddenly, therefore, in raising the centre of gravity of ships you are approaching, bit by bit, at last very closely indeed, a point at which your ship, at least in seaman's parlance, is utterly unstable, though she may possess a stable platform for guns. We are running, day by day, the question so fine, we are making the bottom so light in the endeavour to carry extraordinary weights, that we are likely to ignore other and most serious consequences. And all the while naval architects, or some of them, are saying, "raise your centre of gravity; there is "nothing like raising the centre of gravity; she will have a stable platform for your "guns." But if she be likely to drown her whole crew, does it matter to me whether she lose many men or few in action? Am I to seek the minor security of firing guns at long ranges in preference to the major security of the ship and her crew? I have shown you the curve of buoyancy in this model of mine in a rough way, now I will observe, with due submission to those who know much better on the

subject than I, that it is quite possible we may find in a mathematical consideration of the curve of buoyancy, it may be only necessary to find out what is the perimeter or outline of our floating body, and to consider that the curve of buoyancy must necessarily more or less correspond with that. It is clear that if in inclining this model of the "Captain," as Admiral Fishbourne has well observed, I lower the bilge, and therefore the outline of the containing body, on which depends the buoyancy, I am increasing the column of pressure by the additional depth. That column of pressure will operate, I think, as the squares of the distance, very nearly.

Mr. OLIVER BYRNE: On the distance of the centre of gravity?

Captain SELWYN: The increased depth will give in additional buoyancy, very nearly as the squares of the additional depth.

Mr. BYRNE: The difference in the squares of the top and bottom—the square of the lower to the upper—the difference of the square of the two depths.

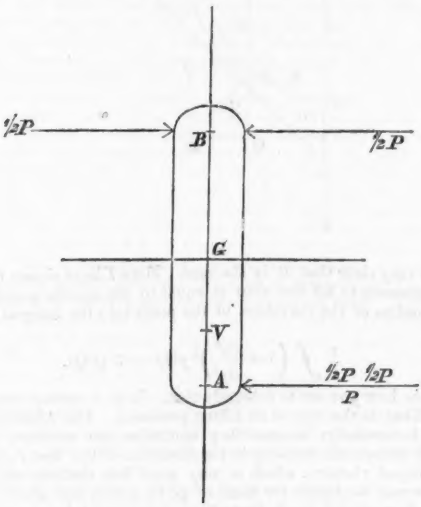
Captain SELWYN: Now, you will observe up to a certain degree of inclination, more buoyancy is being added as I go down, but after I pass the radius drawn from the axis of motion, I cease to have any buoyancy added, and I begin to feel the additional power of leverage due to the inclining weights above. That goes on increasing, while this (the buoyancy added) is coming to nothing; so that, at a certain point, though my ship may be very stiff indeed up to that point, she will suddenly turn over. I need scarcely say to this meeting that the buoyancy ought to be increasing below, *pro rata* with the increased leverage above, and this may be done by good form, but it is not so here, for the instant the radius is passed, as you would easily see, we shall fail to get any additional depth. The radius due to the axis of motion will then come into play to limit it, and I shall get no more resistance while my pressure is increasing. That is an important point; it will show you that ships safe up to certain degrees of inclination, are utterly unsafe the instant they pass them. This model of mine is capable of showing also another point, which I think has not been shown in the same way before. I have put it on a pendulum. Now I will show you the additional force of rolling brought into play by any translation of the mass, by moving that pendulum. My ship may be rolling with a roll due to the sea, or due again to that wretchedly fallacious mode of calculation which applies either a weight on deck or a pulley at the mast-head, in order to determine what the ship's stability is. Mr. Rawson and Dr. Woolley have both pointed out, that in trying all models the force which statically applied was sufficient to incline the vessel 10°, that is to say, applied as if to the pulley at the mast-head, if applied as a dynamical pressure suddenly, inclined her 20°. And you may see how in the water the frictional impulse of a wave passing, may determine rolling far in excess of that which will be due to the ordinary inclination from wind of the vessel. Therefore, you must have a very large reserve of safety. We cannot consider anything safe that will turn over under any circumstances. And now, if you want to gain that power of standing upright, by means of force, still keeping to your modern ship, there is but one way with which I am acquainted as being capable of doing it, and that is to increase the fullness at and above the water line, otherwise we shall have to adopt the system of the lifeboat, which, having a light bow, an impermeable bow and stern, cannot be turned over. That also was the principle of the "Great Harry," and other vessels that had a low freeboard combined with a high poop and stern. It is also the principle of the Dutch galliot and the Chinese junk. It enables all of them to have a low freeboard amidships with perfect safety. Short of that, I know of no better adaptation to the power of carrying a heavy weight amidships than the section I have shown there (Diagram A). Now I am going to speak for two minutes on a totally different question which has suggested itself to me, and I am not aware that it has been hitherto proposed, which is that of the action of a vessel forced against a sea, either by steam or sail, of which vessel the deck is exposed to the entry of water on the lee side. This is to be considered especially with reference to the double inclination due to the pitching, first, and heeling, second. It will be quite clear to anybody who considers the question, that whatever water enters on the lee side, operates as a distinct pressure on that lee side. The plane of the deck is then in the form of a screw, and if I forced that plane against the water ahead,

either by steam or sail, I do my utmost to overturn that ship. I have another model here which I should explain. It occurred to me that it was possible to construct a model, in which the weights should be transferable at pleasure to either side, or to the middle, to the upper part, or the lower, and by introducing a branched glass tube containing mercury, with three branches, one in the centre and one at each side, you will easily see I can obtain any disposition of weights I think proper. This is for experiment on that, firstly, and for the determination of the effect of waves, secondly. But it has another use. Admiral Ryder, whose paper was read at the same time as Admiral Fishbourne's, has spoken of battens for observing rolling. I have no great confidence in their use, first, because the ship is not quite immovable on the sea, but is subject to be raised and lowered by the waves, in which case a correction unknown would have to be introduced, limited only by the height of the waves, and, besides, at night or in a fog, battens would be utterly useless, for then you could not see the horizon. Thus far, I think by taking this branch tube containing mercury, I can very easily get a small instrument which will register at all times the inclination of the ship, without the slightest liability to error. That instrument I shall show on a future occasion. I regret to have occupied the time of the meeting so long.

Captain Colomb, R.N.: Admiral Fishbourne calls us to debate "whether the low freeboard is really the sole cause of the catastrophe." I have not understood that anybody ever thought or said the low freeboard was the *sole* cause of the catastrophe. Having mentioned it, I will leave it for the Admiral to settle afterwards. His third definition is stability arising from the inertia of weights, resisting motion, or persisting in motion, termed relative immobility. I have not quite understood that the dispersion of the weights could have any effect upon the stability, but only upon the unsteadiness of a ship. I thought when the weights were concentrated about the centre of gravity, a ship would be very easily moved, but at the same time she would be as easily stopped; and I have always understood that the idea was to collect the weights about the centre of gravity in order that a ship, though easily moved, might also be easily stopped; that is to say, that when set in motion by one sea, the ship would not have a motion of her own over and above that given by the sea, but would stop when she got over to the amount of roll which was due to the sea. The object I take it we have in view in getting a steady ship is to have one whose deck will remain parallel to the plane of the sea, whatever the nature of the sea may be, in the same way as the plane of the raft remains parallel. If I understand Admiral Fishbourne rightly, he proposes that the weights should be dispersed from the centre of gravity, that is to say, that they should be collected towards the masts, towards the upper parts of the ship, and towards the lower part of the ship. The effect of that, as I understand it, would be that a ship would roll heavily and deeply. (Mr. Henwood: If you had it to too great an extent. The Admiral does not mean to take it to an enormous extent.) Such a ship would represent a section of a fly-wheel: once set in motion, the tendency of the ship would be to continue her motion. Such a ship I imagine would remain very steady through a certain amount of sea, but she would get into some particular sea which might in one or two rolls render the safety of the ship a matter of doubt. I only wish now to say one final word. I am sorry that the Admiral called upon younger Officers to approach the subject of naval architecture with something akin to contempt for it. To my mind it is a very difficult study, and I cannot understand that we, as naval Officers, would be right in looking upon the thing in any other way but with great reverence. I think it is most unfortunate that the education of naval Officers is not carried so far in those directions as might be, because I think were it so, we might give the architects very great assistance, and I think they would much more readily accept that assistance from us.

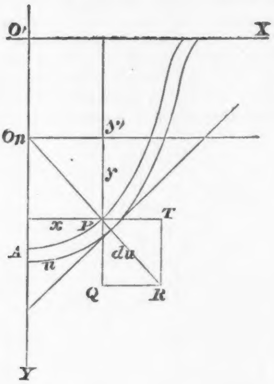
Mr. Oliver Byrne: No matter what impulsive force is applied to a body, or how that force is applied, all that force is applied to turn the body, as well as to drive it on. Now what is the meaning of this simple proposition? This irregular figure, AGB, is a body placed anyhow, in any place, at liberty to move in any way. The force P, or two forces each equal to half P are exerted at the point A; P has the power to turn that body, and to drive on the centre of gravity. You have then

to consider the centre of oscillation, the centre of percussion, the centre of spontaneous rotation; you have nothing to do with the centre of gravity once the force acts upon a body and attempts to move it. If we apply two forces each equal to half P at the same distance from the centre of gravity G, they would balance each other, they would do neither good nor harm to the progressive or turning motion. But we now consider another arrangement of these forces; half P and two half P's here will drive on the centre of gravity; the other two half P's will turn the body round with a force of P. Two half P's will turn it round, and the other two half P's will drive the body on, so that the whole force of P is moving the point G in a straight line right on impulsively for a distance; the other two half P's will turn



the body, consequently the force P acting at A loses none of its effect to turn the body, nor any of its driving effect. What will happen? Why, then the point A will advance by two forces, the force of turning, and the force of percussion, while the point B will advance by one force $= \frac{P}{2}$, and will turn in an opposite direction; the result will be the difference, so that the point B will recede while the point A will advance. Therefore this body will turn round a point near to B, which is called the centre of spontaneous rotation. We lose G altogether. That happens with every force acting on a ship, whether the wind or whether the waves; no matter what the action is, no matter where the forces are applied, whether under the ship or over the ship, every one of those forces has had the effect of the power at A, to determine a point called the centre of spontaneous rotation. French writers have been telling you of what is called an envelope in mathematics, a line or a surface that will take in all these curves. This will make a twisting surface, such as you may see the masts of a ship make in the air. That is not like a pendulum, but forms an irregular figure, somewhat like a figure of 8, and there is a point called the centre of spontaneous rotation in that imaginary line, and a similar figure is passed through on the bottom of the ship, where Admiral Fishbourne has assumed all the forces to be—outside the ship. The Admiral has shown you in

his paper that the centre of buoyancy, the lifting principle, is on the outside of the ship, and not on the inside. That has never been stated by any naval architect



before, and it is very clear that it is the case. Here I have shown that the sum or all the direct pressures to lift the ship is equal to the specific gravity of the water divided by the radius of the curvature of the point into the integral of that expression:

$$\frac{s}{r}\int\left(1+\frac{dx^2}{dy^2}\right)^{\frac{1}{2}}y^2dy = \Sigma\,(PQ).$$

The question is how you are to integrate that. It is a matter merely of mathematical skill. That is the sum of all lifting pressures. The Admiral does not take any pressures horizontally, because they neutralize one another, but the lifting pressures are all underneath the ship in the direction of the line P, Q. But several here have employed rhetoric, which is very good, but rhetoric will never build a good ship. It would be better for them to go to school and study a little mathematics. It has been stated justly that science can never take the place of common sense, nor common sense the place of science. But to come to the question, the point is to sum the forces perpendicularly acting upon a ship, and each of those forces have the power of turning the ship without loss, and the power of driving it also, yet the moment these forces of turning and progression begin to act, the centre of gravity is lost, we immediately establish the centre of spontaneous rotation, the axis of which is perpendicular to the ship. They have all their plans up in the air. The line I am speaking of is perpendicular to them. Unfortunately those that investigate the question mathematically, make imaginary forms in the air. The line I have indicated should be in the ship, and not drawn in the air, consequently if these points in the Admiral's paper were mathematically elaborated, the paper would be an indispensable requisite for those naval architects who were desirous of success, rather than of drowning the captains of ships and their crews.

Mr. MACINTOSH, C.E.: If we take for granted what was stated at the Court of Inquiry at Portsmouth, we are told that the "Captain" was going along in line with reefed topsails, inclining to an angle of 14°; Captain Burgoyne was on deck; she had her steam up; and there can be no question that after letting go the sheets, he might have luffed up to windward. But I believe the moment of danger had arrived, that there was scarcely time for that. We find—we cannot call it a hurricane—it was simply a brisk gale, and the pressure of the atmosphere did not range over 10lb. per superficial foot. But during the many hours or days that the waves accumulated

force, and the ship drawing 25 feet of water, you will find that the water being 800 times heavier than the air, the velocity of that tumbling over-sea, striking her at that angle, struck every foot of the surface like a sledge hammer. Instead of 10 lb. to the foot, it was tons. Take, for instance, those tumbling seas that come over, and then dispassionately look at the action. The upper crust of the sea travels with a velocity 50 per cent., aye, perhaps 80 per cent. quicker than the lower portion. From my experiments in submarine navigation I have found at a depth of 20 feet, all is quiescent, whereas at the surface it rolls along with irresistible force. We know perfectly well that with a vessel inclined over at an angle of 14°, the sea striking her at that angle, acts precisely like an overshot wheel. Here is the fact that the hurricane deck touches the water. The sea strikes that with, I may say, three or four hundred tons. But what I was going to remark was this, that the "Captain" might have formed a proper and safe vessel for years had it not been that the sea struck her in that peculiar position. You should bear in mind that in a vessel drawing 25 feet, when a sea strikes the upper portion, she cannot get away like a shallow vessel. She becomes absolutely a kind of breakwater in the lower portion of her; whereas, from the action of the water on the upper portion, the impact is so enormous, that the tendency is to shove her right over. I was shoved over in a vessel myself, with nothing but a small hurricane deck, having only 6 inches of freeboard. I am perfectly convinced that the enormous impact of a sea, striking a vessel with great depth of broadside on her, is the principal cause of the "Captain" being upset. It is perfectly clear that the moment of danger had so arrived, that Burgoyne had no chance, that the result happened in such a manner that the most practical sailor would have been equally disabled from acting. She was over on her beam ends in a few minutes. Depend upon it, if we only judge of the enormous force of a sea striking a vessel that cannot get away, we may find in that, an explanation of the catastrophe. I have myself rode out the most severe gales off Cape Hatteras, in steamers with hurricane decks, and with even a cabin on deck. But then they were of small draught, with sponsons out. The sea really got under precisely as it would under a duck; it slipped under, and the vessel got over. But in the present case, one portion of the ship is so low down where the water is, that it cannot move, and on the upper portion the sea is coming with such enormous velocity, that the leverage turns her right over. The "Captain" might have sailed twenty years, and not have got into that position again. I believe, had she not been sailing in line, and had Captain Burgoyne exercised his own judgment as to the speed of the ship, the "Captain" would be safe now. Indeed, I wrote a letter to the Court of Inquiry at Portsmouth upon that very point.

Mr. Edwin Henwood, Naval Architect: I desire to make a few remarks on Admiral Fishbourne's paper. It is one which deserves a great deal of critical discussion. First of all, he says, "I think it will be clear to many that till experience had been swept "out of the Constructive Department of the Admiralty, and true principles given to "the winds, some of the ships mentioned, and others, would not have been built, nor "the 'Captain' have been accepted; for, though Messrs. Laird designed her, the "Officers of the Admiralty alone possessed the means of determining the actual "quantity of initial stability that such an ironclad should possess." With reference to that statement, it is only right, on behalf of naval architects out of the Government employment, to state that I must take exception to the statement that the Officers of the Constructive Department alone possess the means of determining the actual quantity of initial stability an ironclad should possess, for that would be to admit that there is nobody else but the Admiralty employés who are capable of ascertaining the stability of a vessel. I fully agree with Admiral Fishbourne in his remarks that the responsibility of the loss of the "Captain" rests upon those who failed to give the necessary information as to her stability to her Officers. I must say I was astonished at reading Mr. Barnaby's evidence at the Court-martial, on the loss of the "Captain," when he stated he saw no danger in a vessel having a low freeboard with the centre of gravity only 2 feet 6 inches below the meta-centre, when he had some years before apprehended great danger in a similar vessel with the centre of gravity 9 feet below the meta-centre. Further on, it has been asked whether she had sufficient initial stability. On this point I must say that on first hearing that the

centre of gravity was only 2·6 feet below the meta-centre, I expressed my surprise in no measured terms, and wondered how those who were responsible for her could have permitted her to go to sea in such a state. There was great negligence even in permitting her to leave Birkenhead without ascertaining practically the position of the centre of gravity. For instance, suppose after leaving Birkenhead she had capsized before she got round to Portsmouth (as was the case with some Swedish ship about 100 years before, as recorded by Captain Chapman, of the Swedish Navy), who would have been responsible for it? It seems a great pity that the Messrs. Laird did not ascertain whether she was safe to send to sea, especially after finding that she was (by the recorded statement), about 20 inches deeper in the water than they intended her to be (when floated out of dock). And especially does this negligence appear the more culpable, because the position of the centre of gravity in the *vessel as built* differs in the wrong direction by about two feet or more from the position as calculated. Mr. Laird is reported to have said that he estimated the centre of gravity to be 3 feet below the 25 feet water-line, therefore 22 feet above the keel, or 1 foot below the *constructed* load-line of 23 feet, and possibly 18 inches below the meta-centre. It would be more desirable to know the position of the centre of gravity as calculated. Now I maintain that the builders of such a vessel, on account of its being an exceptional vessel, should have, immediately the vessel was floated out of dock, ascertained (by data derived from inclining by ballast) the position of the centre of gravity of the vessel in her then state of completion from which they would have been enabled to adjust the centre of gravity by a fresh disposition of weights, or if absolutely necessary, by an alteration of the height of the spar deck or the reduction of the height of the turrets. Even if half-a-dozen experiments had been necessary they should have been made; the cost thereof would have been nothing compared to the fearful sacrifice of life which has taken place. Had such a course been adopted, I am sure we should not have had to deplore such a fearful loss. I am inclined to believe that to the high position of the centre of gravity, *primarily*, combined with the low freeboard, the capsize is to be attributed. It would be desirable to know the weight of the masts in reference to the other equipment of the vessel. Truly it has been said, that the Constructive Department of the Admiralty have gained all the knowledge they possess at the public expense, and it would be well if they were made to pay for their blunders out of their own pockets. It should be known that shipbuilders have often to guarantee, under heavy penalty, that the draught of water of a vessel shall not exceed that stipulated, or to forfeit £200 to £300 per inch for every inch excess of draught.

Commander W. Dawson, R.N.: Suppose Admiral Milne had telegraphed from Corunna that an ironclad ship belonging to his squadron had gone to the bottom, and any number of men who know anything about those classes of ships had had a list of the squadron before them, would there have been any doubt in any man's mind which of the ships had gone to the bottom? But if we had consulted these transcendental mathematicians, we should have found ourselves perfectly wrong in naming the "Captain" as the missing ship, because the lecturer's paper clearly demonstrates that the "Monarch" or the "Inconstant" was the ship which ought to have gone to the bottom. Here we have fact on one side and mathematics on the other. The "Monarch" and the "Inconstant" ought, we are told, to have gone to the bottom before the "Captain," because their distances between the meta-centre and the centre of gravity were smaller than that of the ill-fated ship. Mr. Henwood has truly pointed out that it is perfectly fallacious to compare the distance between the meta-centre and the centre of gravity of ships of different builds. I ask why was it that common-sense people, without any knowledge of transcendental mathematics, would have named the "Captain" as the missing ship? Simply because she is not the first, by a long way, of the low freeboard ships that have gone to the bottom. It is perfectly foolish to compare a low freeboard ship of war with a living cargo and engines, requiring air and full of breathing holes, with a Thames barge that has a dead cargo, covered in with watertight hatches from end to end. Any accident to these breathing holes, or laceration of their casings, must be highly dangerous. You will remember that the original "Monitor" went to the bottom at sea without capsizing; the "Keokuk" went to

the bottom at anchor without capsizing; the "Affonditore" went to the bottom in port without capsizing; the "Captain" went to the bottom, not by rents in her breathing-pipes, but by overturning; and if the other low freeboard ironclads have not yet gone to the bottom, it is simply because they have been so carefully nursed and kept out of harm's way that they have not had the opportunity of doing so. The general tendency of what I gather from this discussion is this,—that most of our ironclads are unsafe, and that is a thing that it would be very wrong to send forth from this Institution as being the opinion of naval men. Take the illustration used in the paper. There were in the China seas two ships exposed to typhoons. I would say in parenthesis, that a bad gale does not, as a general rule, mean a bad state of the atmosphere, but a bad condition of the ship; and if it happens to be a ship of the mercantile marine, an overcargo of marine insurance, it has nothing to do with the atmosphere, as a rule. There is no doubt, however, that these ships were exposed to typhoons; one of them was an ironclad, the "Ocean," the other a line of battle ship, classed according to its height of meta-centre above the centre of gravity, as an exceedingly safe ship,—one of the finest line of battle ships in the service. The so-called unsafe ironclad goes through the gale without going on her beam ends, whilst the "Conqueror," with the larger distance between the meta-centre and her centre of gravity, is thrown on her beam ends. (Mr. Henwood: Would you allow me——.) Time is precious; I would rather make a few mistakes than lose time. The general bearing of what I am going upon is not transcendental mathematics, of which I know something, but common sense. I will keep to the general line of argument. At any rate, the "Conqueror" was thrown on her beam ends. The difference between a high-sided ship and a low freeboard ship in that position was skimmed over rather by the lecturer. When the "Conqueror" was on her beam-ends, the whole force of the typhoon, beating on the weather side and bottom, was received in a thrust on the lee side by the water pressing against the whole of the broadside; and that part of the thrust extending from the lee water-line up to the gunwale, all tended to keep that ship on her legs until a lull in the typhoon admitted of the usual nautical evolution for her reinstatement. But, cut out the two sides of the "Conqueror," from the gunwale to the lower deck, leaving all the decks standing, and you will have a low freeboard ship with her hurricane deck. The whole of that thrust which, pressing against the lee side of the high-sided "Conqueror," tended to prevent her overturning, will now be received upon the decks of the low freeboard ship, pressing her down. You will thus have the typhoon on one side and the thrust on the other acting together, uniting their powers to turn the ship over like a water-wheel. If a low freeboard ship gets at all inclined over to her beam-ends, in the position of the "Conqueror," she is sure to turn over, whether the pressure on her decks be that due to leeway. or that due to headway; the latter pressure against the lee side of a high-sided ship, tends to keep her upright, but on the deck of a low freeboard ship tends to turn her over. I do not know whether I am quite in order, but seeing Sir George Sartorius before me I cannot help thinking as I look at these low-sided vessels as ships of war liable to take part in general actions, that Sir George is the very person who, if he saw a thing of the kind proposed by Mr. Henwood, of several thousand tons burthen, and with only 3 feet 6 inches freeboard, would run over her with the smallest vessel in the Fleet. Such a thing was very nearly run over in action during the late American war. The "Albemarle," a casemated ram, with a low freeboard, was nearly overridden by a small wooden vessel, which got the ironclad ship down till the ports came so close to the water, that a few inches more would have sunk her, if the vessel had got her forefoot a little further on the deck, or if she had been a little heavier, or if the water had been less smooth, the low freeboard ship would have gone to the bottom. As to a Henwood monitor, even if it can be made as safe against the elements as a high-sided ship, you might as well send our seamen into a general action on a hencoop.

Captain Goodenough, R.N.: Having been a member of the late Court-martial on the survivors of the "Captain," I am entirely precluded from expressing any opinion of any description on the cause of her loss.

On the general questions which have been raised as to the stability and steadiness

and other qualities of ships in general, I think one can hardly listen to the observations that have been made by our gallant lecturer, and remain silent. As a naval Officer, I do not wish to be supposed to participate in all the opinions which the lecturer has there pronounced. I am very sorry that we have not had the opinions of the lecturer fully discussed here by naval architects, but, I must confess that I am not altogether surprised, for (although we have had the advantage of the presence of naval architects not belonging to the constructive department of the Admiralty), yet I must say the tone of the paper was such, although some latitude must be allowed to a speaker when he is carried away by his subject, yet the mode in which some of the pointed remarks were received in this audience was such, that I am not at all surprised at any of those very talented and able gentlemen who belong to the Constructive Department of the Admiralty remaining away. I should have been surprised if they had come here, after the pointed remarks made as to them, and I regret exceedingly their absence. I am sure I shall carry with me the feelings of many members of this Institution in expressing that regret, for I am bound to say that those gentlemen who belong to the service of the Crown, equally with ourselves who are Officers in the Fleet, are animated by as high a sense of honour and desire to do their duty to their country, and to improve the state of naval architecture in this country, and are as glad to carry improvements into the public service, as any body of Officers under the service of the Crown. Therefore, when we ask them here to participate in our discussions, we are bound to treat them with that courteous deference to their opinions, and their well known knowledge—that their position demands.

Now, for my own part, I cannot help referring to one or two things which I see stated in Admiral Fishbourne's paper. He says,—"To give a ship little statical stability is to "injure every one of her qualities, and the idea that in proportion as a vessel is without "stability up to a very small limit she does not roll, is without reason or fact to justify "it." I can only say, in answer to that, all the experience which we have gained in the past years in the Channel squadron is totally adverse to it. We do find, as the distance between the meta-centre and the centre of gravity is diminished, the rolling of the ship also diminishes. (Admiral FISHBOURNE: Will you kindly give proof of it. You may assume it to be anything; it is another thing to prove it.) That is my opinion; I won't say assertion, I should be sorry to assert, but as my opinion is called in question, I may say that that opinion is justified by many tables of the movements of ships which are in the power of everybody in this assembly to purchase; everybody can refer to those papers. In connection with that point I must further observe that the addition of light wood to the beam of the "Captain," or of the "Invincible," or other ships which are found to be very crank, is well known to be a means of altering their qualities very much by increasing the distance between the meta-centre and the centre of gravity, and so diminishing their rolling. Further on I observe Admiral Fishbourne mentions, "a further "injurious consequence of the sails, owing to their great inclination, is the "directly pressing down effect from the position the lower part of the sails is brought "into." I cannot altogether agree with that, and I am bound to point out that it is in direct contradiction to a further paragraph in the paper, where the inclination of the vessel is stated as arising from the diminution of the oversetting power. (Admiral FISHBOURNE: No; it is not contradicted.) I am in the hands of the meeting, and Admiral Fishbourne will have the opportunity of correcting me. That is my own impression. Another point I shall mention is that, as I am sure that Admiral Fishbourne would not assert that you can take the effect of the weight of a ship, and divide it as you like, so you cannot take the effects of the buoyancy to pieces and divide them about the ship; but it seems to me in the theory which Admiral Fishbourne has put forward about the effect of the buoyancy of those cells in the bottom, he has done this. We are discussing principles here, and I should be very glad if Admiral Fishbourne would further explain the doctrine he has put forward as to the up setting quality of these cells in the bottom of the ship taken separately, and not in connection with the remainder of the buoyancy. In connection with this point I may notice that although the oversetting quality of those cells has been noticed in condemnation, still that in another place in another part of the paper,—which seems to be in contradiction with this,—Admiral Fishbourne has favourably noticed the

heightening of weight which is afforded by the masts of the ship, and has said that to take the masts out of the ship, would probably injure her qualities. The masts of the ship we know are so much weight added above, and so much heightening of the general centre of weights in the hull of the ship. That is another point on which I should like explanation. There are many other points, but they are too numerous for me to go into. I do not pretend to refute them, but merely wish to draw attention to their existence, and to say that I think that their refutation is to be found in many works on naval architecture, and I hope that Admiral Fishbourne will give us a further explanation on those points to which I particularly refer.

Admiral RYDER: A gentleman opposite asked a question as to what was the opinion of naval architects as to the effect of the hurricane deck, and the pressure of the wind underneath it in helping to turn the ship over. I am confining myself to the effect of the wind. The question was discussed. I was at the Court-martial, and the question was asked of the experts present there, the gentlemen from the Constructive Department, and in their opinion, from the construction of the hurricane-deck at right angles to the masts, the effect of the wind on it was nil, or almost nil. I merely state this as their opinion.

The CHAIRMAN: I will now call upon Admiral Fishbourne for his reply.

Admiral FISHBOURNE: With reference to the remarks of both the Messrs. Henwood, who seem to imply that I was disparaging the abilities of private naval architects in supposing that the Admiralty constructors alone were aware of what would be sufficient initial stability in an ironclad, I was dealing with a practical question. If there is one thing more distinct in Mr. Childers' minute than another, it is that the general experience of Admiralty surveyors and architects was that every private builder had underrated the weights that his ships had to carry and that the consequence was too great immersion. They gave two notable examples of that. One was built by Mr. Laird and another by Mr. Smith. One was immersed 2 ft. 3 in., and the other 2 ft. 10 in. The "Captain" herself is an illustration of that. The Constructor's Department guarded themselves against that in vessels of their own construction, and in vessels built by contract, by giving orders to their inspector to take particular care that the weights in detail should not exceed the gross estimate. The "Captain" as designed was a good vessel; as constructed she was a bad one. The failure was that she was immersed 800 tons more than she ought to have been. The officer who ordinarily receives instructions to see that the weights are not in excess, "did not receive usual orders" in the case of the "Captain." I hope Mr. Henwood will understand that I was urging the value of practical experience. However good theoretical knowledge may be, it is practical experience that will enable the architect to carry out his theoretical knowledge. Mr. Henwood, also Captain Colomb, objected to my dividing stabilities into static and dynamic stability of inertia. I did it for clearness, because these had been confounded together, and because things were assumed to be true which were not founded on fact. One of these assumptions Captain Goodenough has been good enough to tell us of, but which he did not prove. I believe it is because the distinction was not kept up in the mind. People found a ship with what I call large stability of immobility, great inertia of the weights, and they jumped to the conclusion, because that vessel did not roll much, that it necessarily arose,—as if there were no other cause in action,—from the simple fact that her centre of gravity was higher than in another that did roll. I utterly deny the assumption, and have given proof to the contrary, and I expect when contradicted that proof should be given, until which my proof must stand. With respect to a remark of Admiral Halsted, who mentioned the case of raising the centre of gravity in one of two sister ships, the "Achilles" as compared with the "Warrior." I stated—and it can easily be proved—that the difference arose from the greater distribution of the weights, and their greater moment of inertia, and that the ease or steadiness in the "Achilles," as compared with the "Warrior," arose from that circumstance. None of these ships have passed the crucial test yet, which they ought to have done before a definite opinion could be given. Do not compare things that are not comparable. Compare the ship with herself, or have a standard ship, keep her in her best condition, change the other ships, and then compare the effect of that change in them. Lighten them of their weights, raise their centres of gravity, and I

am sure there will be in every case, an increase of the arc of roll; it is impossible to be otherwise. I have put nothing transcendental in my paper. I speak as a practical sailor, and I assert it is a fact, that there is no instance on record where the centre of gravity alone has been raised in any ship where the arc of roll has not been increased. In my experience as to this, fact and demonstration go together. I understood Mr. Henwood to say that Professor Moseley had introduced the word "dynamic," with respect to a particular mode of determining the stability of ships by the rise or fall of their centres of gravity. The word had been introduced long before. It is perhaps better known among naval architects as "hydro-dynamic stability," but it is substantially the same thing. He went on to say, as I understood, that that dynamic stability which he attributed to Mr. Moseley only occurred in badly formed ships. But there is a dynamic stability, or, if he will have it, hydrodynamic stability, which arises entirely from progressive motion. The faster a ship is going, the greater is that dynamic stability. Every sailor is aware that when a breeze strikes a vessel or boat that has no motion, the first effect is that the vessel inclines very much, as she gathers way she stands up under the pressure of her canvas; that is, just as the dynamic stability increases by her motion, therefore it cannot be ignored. And there is where naval architects have failed in producing the greatest results, because they have overlooked that which is a most essential thing. They have built ships to suit conditions, to be found only in harbour, instead of for conditions which are to be found at sea. This is where the danger is greatest, and this is where the dynamic stability is most essential. I do not know whether it is in the paper, but as I wrote it originally, I used this expression, "relative immobility, which resolves itself into dynamic stability." I used it for clearness, and I believe it is essentially necessary, because these things get confused, and they have latterly got more confused than ever I saw before. No one who understood the value of dynamic stability, and how it was obtained, would have given a ship a full bow. The recommendation with respect to ballast was an immediate remedy for a dangerous evil. Mr. Henwood said, and the same idea also came from Captain Colomb in a somewhat different spirit, that I was proposing to make "a jack of all trades, master of none." I quite concur in the idea that to attempt to make men sailors, soldiers, and naval architects would be an absurdity. They would be neither sailors nor soldiers, nor naval architects. But I say where there is a naval Officer who is a sailor, and who possesses a turn and talent for naval architecture, utilise his talent. But to take men who know nothing about seamenship, and who are not in the way of it, and to fancy that they can be made naval architects at the school at Kensington, is an utter absurdity. They have no means of learning the mechanical part of their profession; they are not brought into contact with sailors who have practical knowledge, nor with things to suggest to their minds questions which it is indispensable for the naval architect to be acquainted with. Again, what are they being taught, the no-stability scheme of spoiling our ships? Why, the naval architects are not at one about their own science; they are as opposed as light and darkness. Then, as to the remark of Captain Colomb that I called upon young naval Officers to study naval architecture, and that I threw contempt upon it. My whole paper is a contradiction to that. My whole life is a contradiction to it. From the earliest days of my boyhood I have thought upon the subject. Am I, then, likely to throw contempt upon naval architecture? No; but the disgraceful loss of those men in the "Captain" has thrown contempt upon it. The nonsensical things that have been put forward, throw contempt upon it. I was endeavouring to redeem it from contempt by endeavouring to show what it ought to be. I was endeavouring to bring forward the true principles that are to be found in the best authorities. I do not profess, except on those important points which have been alluded to by Mr. Byrne, to claim any originality. Mr. Henwood alluded yesterday to his father, as if I desired to appropriate opinions of his. I had great respect for his father. He was an able and an honest public servant. I should be exceedingly sorry to deprive him of any right. He first drew my attention to the importance of a proper distribution of weights, and I am glad to acknowledge it. I put it forward because it was neglected; notwithstanding that it had been put forward with clearness, and was long before the public, and was reiterated in works by Creuze and others, and the

importance of it shown. Captain Goodenough asks me to explain how this distribution is to be made. I beg to refer him to Mr. Henwood's paper on the subject. Another speaker said that Mr. Henwood had corrected me with respect to the adoption of the meta-centric height. I accepted it as I found it in the books of the Institute of Naval Architects. It is more correct than Mr. Henwood's. The "Captain" is a characteristic illustration of it. He says you must introduce the weight. Now, what is the fact? It was the weight that spoiled the "Captain." So that which would spoil the ship, it is proposed to bring in as a multiplier to cover up the extent of the defect; for that is really what it would amount to. It would be perfectly easy to so arrange the "Captain" as to reduce her weights and yet increase her stability; I mean, as compared with what she was, by making her what she ought to be. I did not insert it as an absolute measure, but as relative; particularly as respected ships of a similar kind. Mr. Henwood made some remark about the water as shewn at the vessel's side in the drawings; I did not not precisely gather what he meant. But I may say that it is impossible to represent all that I wanted to represent. Any sailor who has sat watching the seas, as I have for hours, will know perfectly well that when a sea comes towering over, apparently going to break on board, all of a sudden it lifts the side of the ship up and passes under her. The water does not come up to the side at all, because the vertical forces, as shewn in Pl. IV., acting on the bottom of the vessel, lift her bodily up. If she had not been lifted up in that way the sea would have broken on board. With respect to the hurricane-deck, I believe I may give an answer. It appears to me that the discussion with respect to the hurricane-deck was pretty much like the idea of the alderman who, having had a severe fit of gout,—after considering the subject for a long time as to what could have caused it,—remembered that he had eaten a ship's biscuit! and sagely concluded that it was the cause. It is really just as pertinent as to attribute the loss of the "Captain" to the hurricane-deck. Anybody who knows anything about mechanics must know that if a plane be placed at an angle to the direction of the wind to act on its lower surface, much of the force will be vertical and tend to lift, in fact to make it rise like a boy's kite, therefore the hurricane-deck so far tended to keep the ship up; whereas, had she had a high side like the "Monarch," which, besides presenting a much larger surface for the wind to act on as the vessel inclined, it would act on the upper surface and tend to press her down and over. As to low freeboard, I was not advocating such. I proved there were forces in operation, before the ship's inclination arrived at the edge of the freeboard, enough to destroy that ship, apart from any question of freeboard, therefore having proved that, was it necessary for me to discuss the question further? It was really foreign to the matter. There was another question, as to the effect of the water on the deck. Whatever may be the inclination of the side, if that portion is above the centre of gravity, its tendency is either to support the ship, or negative. No doubt part of the resolved thrust may be downwards, but the leverage of the lateral thrust acting above the centre of gravity tends to counteract that. But granting it, that because of a low freeboard, to have a turning tendency, it is absurd to attribute the capsize to the leverage of 2, or 3, or 4 feet near the centre of gravity when there is the leverage of 23 feet or more in operation all the way down to the bilge, and if in calculating the great effect of this I did not include the less, it was that I did not wish to exaggerate.

The CHAIRMAN: Does not the weight of water, pressing vertically on the deck, shove her down?

Admiral FISHBOURNE: I have already explained the effect of the weight of the water.

Mr. OLIVER BYRNE: No, it presses in all directions. Anything below the centre of gravity acts as a force to turn her round. Anything above the centre of gravity acts the reverse. Anybody calculating the lateral forces only calculates from the centre of gravity downwards, calculating the lateral forces that are acting upon the ship. He deducts the force above the centre of gravity upwards. Anything above the centre of gravity has that action.

Captain SELWYN: Would you integrate that, and show what the result is,—how much force is expended in preventing the wave acting downwards. How much is

the downward force when the power strikes? How much will resolve itself into an upward force, and how much into a contrary downward force of a power striking with 100 lb. weight per square foot on this inclined deck,—how much will resolve itself into a downward pressure if that force be continued?

Mr. O. Byrne: There is no downward pressure, because it is all sustained by the water. You see here is a wall. The pressure on that wall will resolve itself in this way. The weight on the wall is an upsetting force. There is no weight on the wall because it presses in every direction.

Admiral Fishbourne: One of the speakers drew a comparison, unfortunately for himself, between the "Ocean" and the "Conqueror." And he asserted,—like many more of his assertions, it did not admit of proof,—that I passed it over slightly, and that I condemned the "Ocean." I did not condemn the "Ocean." On the contrary, her meta-centre is 6 feet above her centre of gravity, whereas the "Conqueror's" is only 4 feet 6 inches, and 6 feet is the amount which I asserted was the proper quantity. As far as it is possible to praise the "Ocean" on that point, I did. But it was not my purpose to speak of the "Ocean," as I was not aware of the fact he mentions. So far that gentleman is giving a very practical illustration in favour of my paper, while he intended the contrary. Captain Goodenough said there was a contradiction. There is no contradiction with respect to the action of the sails whatever. For when a ship is upright, the upper part of her sails have a lifting tendency, particularly when the masts rake when she is inclined, till the plane of the sails passes the perpendicular, then all parts of the sail will have a downward pressure, and this will increase as the plane, by further inclination, is carried further over out of the perpendicular; and this, though the vertical height, may be less and the total lateral force less, because owing to the force of the wind the curvature of the sail increases, and the lower part of the sail becomes almost horizontal. Moreover, the after part of the sail becomes a back sail and a drag on the ship. Therefore the yards, as the wind increases should be braced in more and more, thus the sails would be less oppressive to the ship, and more effective, too, with the increased speed, increasing her dynamic stability. Neither is there any contradiction in my recommending a lower position of the centre of gravity, and yet the employment of sails as a motive power, since I also recommend a sufficiency of stability amongst other things for that purpose; moreover, the height of the centre of gravity is influenced by the distance only of the centre of gravity of the masts from the common centre of gravity, while the moments of inertia, which are so valuable in limiting the arcs and periods of roll, are increased as the *square* of that distance, and thus they bring with them a beneficial compensation. With respect to the distribution of the weights, I have gone sufficiently into that, and given full illustrations. This whole question is so important that I will sacrifice my time, and come at gentlemen's beck and call to consider their facts, their statements, and proofs. What more can I do? I have nothing more to say, than to thank those gentlemen who have come forward and taken an interest in this question. It is a national question. I am sorry if I have been offensive to architects; it was not my intention or desire to give offence to any one, but to make statements and to prove them, with utter carelessness as to what offence they gave, so only they are necessary for the good of my country and my profession, and are true. I can only say, I believe the Chairman will bear me out that he said to me, "I have read your paper very carefully, and I "do not think there is any expression that is out of place or uncalled for." If Sir George Sartorius thinks there is anything that is improper for a naval Officer, or a gentleman, or a Christian to say in that paper, I shall be glad to withdraw it.

The Chairman: Gentlemen, we have had a long discussion upon a very interesting subject. I am a practical sailor and an old man, and I am sorry to say that I feel very much the deficiency of not having better understood the scientific principles of my profession—it is too late now to correct the error. I agree with the gentlemen who have shown an honourable knowledge of the scientific part; and I quite concur with Admiral Fishbourne that it is absolutely necessary that the scientific should be combined with the experimental. It is for the sailor to explain the kind of instrument or machine that he wants for the particular purposes of his profession. From experience he knows that there are certain qualities which a vessel

must possess, whether she be a merchantman or a man-of-war, and it is for the man of science to turn his skill towards fulfilling the demands and desires of the sailor. But I am afraid this union of the practical sailor and the scientific constructor has not been sufficiently combined in the present case. It was assuredly not the fault of the sailor that the "Captain" was capsized and her 500 men sent to their last home. Surely it was not a practical sailor who was the cause of it. It shows how necessary it is that the two should have consulted well together before the vessel was built, and again before she was sent out to sea. Why, then, should that vessel—a new vessel, constructed on principles which are perfectly new—have been sent *to sea* without every possible precaution having been taken that could be taken for the purpose of previously ascertaining the sea-going qualities of that vessel both in harbour and for few hours at sea before she was sent out to cruize? Had that vessel gone through all those necessary trials, she would certainly have been now afloat. She was built for 800 tons of water-ballast to be placed in the cells in her double bottom, and if she had only had 400 tons of that ballast in her, she would have been afloat now. True, she would always have been a bad man-of-war, but she would have been safe. She was built also for a trial between the low freeboard and the high freeboard. She was immersed more than 2 feet below the draught she was intended for. Therefore, all the conditions required in a fair and honest trial between a low freeboard and a high freeboard were entirely destroyed by that error. That error alone would have justified the Government in giving up the vessel. Therefore, I may well say that the naval architect and the sailor did not go hand in hand in the construction of that vessel. The stiffness of a vessel was, I formerly understood it, stability, and crankness as the danger of overturning. These terms are perfectly intelligible to the architect, as well as to the sailor, and are a sufficient guide. Our practice and experience always enabled us to keep out of scrapes in capsizing vessels. Sometimes, like the corvette, in warmer seas, when, from the prevalence of light winds it was necessary to carry an enormous spread of sail, our ship was made very crank, but our knowing whether she was crank or stiff, experience and watchfulness always enabled us to prevent any unfortunate accident occurring. But it is experience and practice which enabled the sailor to do this; and it is to our experience and practice that I want scientific constructors to listen. I want them to go to sea with us, to associate with the truly practical sailor, and to seek by observations and innumerable questions to clearly ascertain from him what is required, and then to give us what we want. Thus far I bow to science. I again repeat, let the two go hand in hand as friends, equally and mutually interested in obtaining the important objects of their united wishes. As long as experience and science go hand in hand we shall do well. If we are to bow our heads to science, without science consenting to benefit by our experience, the result must ever be most unsatisfactory. I have to thank Admiral Fishbourne, in the name of the Meeting, for a most intelligent and interesting paper; and to thank also those gentlemen who have spoken upon the subject of his paper, particularly those who have taken part in the discussion of this evening; they have given us a great deal of information, which, old as I am, I shall remember with pleasure and profit.

FORMS FOR REGISTERING THE ANGLES OF ROLLING AND HEELING FOR THE INFORMATION OF THE CONSTRUCTION DEPARTMENT AT THE ADMIRALTY.

By Rear-Admiral A. P. RYDER.

THE subject of this Paper is, "A Form for Registering Rolls and Heels." When I was afloat a short time since in the Channel Fleet, I found, on reading the various Reports of the previous cruizes which had been printed by order of the House of Commons, that the Controller, Sir R. S. Robinson, evidently did not consider the records of rolling and heeling which had reached his office, owing to transparent mistakes in them, as of much value.

I enquired at the Controller's office whether much importance would be attached to the records if they were more accurate, as I was under the impression that the mistakes arose chiefly from there being no printed form of registry common to all the ships, and not from any carelessness or neglect. I was informed that really trustworthy observations would be very valuable.

I will now read you an extract from the Report for 1869 of the Committee of the British Association on the stability, propulsion, and sea-going qualities of ships, page 60:—

"With regard to rolling, we have much *vague* observation and but "little exact knowledge derived from experiment;" and, page 62, "We are certain that it has not been published in any available form, "and we have reason to believe that the knowledge is quite as much "needed and desired by the gentlemen responsible for the con-"struction of the Navy as by merchant builders, or by students of "theory."

(Signed) CHARLES W. MERRIFIELD.
GEORGE P. BIDDER.
DOUGLAS GALTON.
W. J. MACQUORN RANKINE.
W. FROUDE.

I was aware, of course, that there were printed forms—here is one of them—but this is only an abstract in which to record merely the *means* of the numerous rolls or heels during each of the five-minute observations (the number of oscillations varied in the different ironclads from 40 to over 60 in the five minutes). What was wanting to ensure accuracy was a *printed* form on which to record the amount of inclination at the extremes of each roll or heel *during the five-minute observations.*

It had been not uncommonly the practice to note the original observations on slates or pieces of paper, which were not preserved, and therefore it had been impossible to trace out mistakes, and dis-

credit was thrown on a mass of observations, many of which were accurate.

Those of my readers who are familiar with records of astronomical observations are aware that it is considered essential that the *original* observations be preserved. This is now secured, as to observations of "rolls and heels," by their being entered in these books which, at my suggestion, are issued by the Admiralty for the purpose. The entries are made in pencil on deck, and are inked in afterwards, but so as to allow the pencil entries to be seen.

At first sight it appears very easy to record the angles of heel successively for five minutes—and when pendulums and clinometers were believed in—the record was a simpler matter than now, when the two battens are alone used and *relied* on, if the horizon is in sight. It is thoroughly recognized now that pendulum observations are not to be depended upon, owing to the proper motion of the ship, which may accelerate or retard the pendulum's motion.

When I first embarked in the "Bellerophon," I had a self-recording pendulum made at Portsmouth, and intended to suspend it as near as possible to the ship's centre of motion, but on learning that no record of pendulum motion would be accepted as of any value when the horizon was in sight, I never used it. As some of my readers may not be familiar with the use of the battens, I will briefly explain them. A batten is placed at each end of the bridge; the zero in each batten is at the same height above the water as the eye in the centre of the bridge, which latter must be at some fixed point, as, for instance, at a notch on the bridge-house, or a piece of twisted wire on the standard compass stand. It will be found that as the upper part of the batten can be indefinitely prolonged, whereas the lower part is of a fixed length, it is necessary to use both battens, the starboard batten to record considerable inclinations to starboard, the port batten to record considerable inclinations to port. The battens are tangents to the angles of heel, and the degrees marked on the battens must necessarily therefore increase in length as they recede from the zero.

When a ship is oscillating through various angles, it is required by the Department that not only the amount of the angles of oscillation be noted, but also the inclination from the *vertical* at each extreme of the oscillation. When the pendulum was the instrument used, the angle recorded at each extremity of the heel or roll was the angle of heel, and if the upper arm of the pendulum was at 10° on the *starboard* side of zero, the ship was supposed to be heeling 10° to port, and *vice versâ*, but when we observe the heel with battens, the zero is in the direction of the horizon, and a heel to starboard, if observed on the starboard batten, will be shown above the zero, and if observed on the port batten will be shown below the zero, confusion is thus introduced, and ships in the same fleet, observing heels and rolls by signal, are found to have made evident mistakes of various kinds. Among other errors the maximum heel was sometimes recorded as less than the mean heel, which is, of course, impossible. Sometimes one oscillation of say from 10° starboard to 5° port was recorded as two heels. Sometimes two oscillations were recorded as one roll.

It occurred to me that a form of record might be arranged which would tend at all events to largely diminish the number of mistakes, if it did not altogether prevent them, and my suggestion has been adopted by their Lordships. I have been desirous of having this form of register distributed by means of the Journal of this Institution to Officers on foreign stations, as I believe the Admiralty only issue them to the Channel and Mediterranean Squadrons when assembled for experimental purposes. It will thus be in the power of every Captain to record from time to time, say once a week at sea, and oftener in gales, and always immediately after leaving and just before entering harbour, the five-minute observations of heels and rolls; these, with the draughts of water, on leaving and entering harbour, and any peculiarity of stowage, sea, &c. (see Appendix, Form B), will afford very useful information to the Constructors' Department of the Admiralty.

If wo ships are in company, the periodic time of, and space between the seas, and their height, should be recorded also.

I will now explain briefly the form of registering the rolls or heels during five minutes, and I have little doubt but that any Captain who applies to the Constructors' Department for a blank book of rolling and heeling forms would be supplied with one, which would enable him to record 100 five-minute observations, or at the rate of three a month during a commission.

This method of recording the observations will be found to facilitate the registry of angles when the ship, heeling over under the action of the wind, yet occasionally rolls to windward of the vertical (see Fxample No. 4). This case was difficult to register previously. The ironclads I have sailed in under the existing sail equipment, appeared to be unable to resist a disposition to roll to windward, but they were equally ready to heel to leeward on the approach of the next wave, and were not wet ships, quite the contrary.

The following is a short abstract of several observations made on board Her Majesty's ship "Penelope," off Lisbon, in 1868–69, which tend to show that although each vessel may have in still water her own periodic time of oscillation, which is invariable, *cæteris paribus*, yet that this is only true within certain limits; under other circumstances, the motion of the waves, a change in the draught of water, the pressure of the sails, may all seriously affect this interval.

H.M.S. "PENELOPE."

Date.	No. of Oscillations. In 5 min.	No. of Oscillations. In 1 min.	Greatest angle of Oscillation during the Observation.
			°
1868. November 28	46	9·2	9¼
" " 30	48	9·6	15½
" December 1	48	9·6	22½
" " 3	48	9·6	17¼
" " 3	50	10·0	18½
" " 5	48	9·6	35
" " 6	53	10·6	45
1869. January 29	49	9·8	34½
" " "	49	9·8	35
" " "	49	9·8	34½
" " "	48	9·6	35½
" " "	45	9·0	25
" " "	49	9·8	24
" " "	43	8·6	33
" " "	46	9·2	40
" February 1	49	9·8	34½
" " "	49	9·8	27
" " "	47	9·4	21¼
" " "	45	9·0	19½
" March 8	52	10·4	36
" " 12	43	8·6	19½
" " 12	50	10·0	15

The mean number of oscillations made by "Penelope" in one minute appears to be 9·5.

In the summer cruise of the Channel Fleet, in 1868, numerous observations were made of rolls and heels, and are to be found in the Report as presented and printed by order of the House of Commons.

The following Table has been arranged to show the comparative rapidity of motion of the various ships, and hence their relative steadiness for gunnery practice.

Name of Ship.	Number of Oscillations in 1 min.	Mean number of degrees in each Oscillation.	The number of degrees in 1 min.	Number of seconds occupied in oscillating through 1°.	Remarks.
Minotaur	7·9	1·4	11·1	6	Very steady.
Achilles	7·	1·7	11·9	5	
Bellerophon	9·6	1·9	18·2	4	
Warrior	9·7	4·6	44·6	1½	Unsteady.
Defence	10·8	5·4	57·3	1	
Prince Consort ..	12·1	7·0	84·9	¾	Very unsteady.
Pallas	12·0	9·0	108·	½	
Royal Oak	13·2	12·3	162·4	⅓	

Instructions for Observing, Noting, and Recording Rolling Motion and Performances at Sea of Her Majesty's Ships.

1. It is of the greatest importance that these observations, the chief object of which is to ascertain the mean rolling and the mean heeling of the ships, should be carefully *noted* in detail in the Form A (*see* directions below for filling up the notation form), and then be abstracted and recorded in the Form B.

2. The observations are to be taken hourly, every day, during daylight, when there is much motion, if the horizon is visible, and at least once in the day whenever the ship is at sea. They are also to be taken occasionally at night by a pendulum, when there is much motion, or under any circumstances which would give value to the observations. When the ship forms part of a fleet, the time for making the observations will be directed by the senior Officer.

3. One oscillation of *rolling* is one roll from starboard to port, or from port to starboard. The oscillation of *heeling* is from starboard to more starboard, and *vice versâ*, or from port to more port, and *vice versâ;* so that a ship heeling over from 4° port to 6° port and then back, to say 3° port, has made two oscillations, one of 2° and the other of 3°.

4. Where a great difference appears in consecutive observations recorded (unless some particular change in the ship's position or in the weather, which should be fully explained, obviously accounts for it), other sets of observations must be taken, and if the difference still exists, the supposed cause must be given in the remarks. When this happens a signal should be made to the senior Officer.

5. When any observations are made by signal, they are always to last five minutes.

6. At least two intelligent Officers must be stationed, one to note the degrees of rolling or heeling, and the other the time; and during the day the same Officers should be employed, if the service will admit of it. When observing with the battens, the eye should always be at the

same place. A piece of wire making an eye-hole, and attached to the rim of the Azimuth compass will answer.

7. No other instrument need be noted, except the "battens," when the horizon is visible. If the horizon is invisible, a pendulum, as near the centre of motion as possible, should be recorded. The degrees on the battens will gradually increase in size above and below o. It will be sufficiently correct to consider the o as exactly the same height above the water as the eye-hole. The degrees on the battens are measured on a tangent, having for a base the distance from eye-hole to o on the batten.

8. The different instruments in use are to be once a day carefully compared by simultaneous observations during five minutes, and the result noted as to the mean degrees of rolling or heeling and mean number of oscillations per minute shown by each.

9. The instruments in use, and where placed, are to be noted on each Return.

10. Each Captain is to keep a journal of the qualities of the ship he commands, under the heads of—

Sailing.	Pitching.
Steaming.	Power of fighting guns.
Tacking.	Distribution of weights.
Wearing.	Dryness.
Rolling.	General handiness.

A fair copy of which is to accompany the Tabular Form at the end of each cruize.

Directions for Filling up the Notation Forms, &c.

11. The accompanying Form A for *noting rolls* and *heels* is to be invariably used when the observations by the battens are being noted. The battens (see drawing) should rest on the deck close to the ship's side at ends of bridge.

12. A specimen is given of "rolling and heeling;" but the printed form is the same for both. This form is to be used for the observations with the vertical battens only.

13. The actual observations are to be noted on this form (and not on a slate, or on any other paper) on deck, in pencil, and then inked in, leaving the pencil entry still showing.

14. The original Forms A are not to be sent in to the senior Officer at the end of the cruize, unless called for. The Forms B are to be sent to the senior Officer as soon as possible after the cruize is finished.

15. The Form A has been ruled so as to enable sixty-five rolls or heels to be noted in five minutes, which it is believed will be as many as the most rapid ship will make in five minutes. The form can be lengthened if necessary.

16. The total *results* are to be filled up in the blanks left for the purpose on each side of Form A, and then transferred to Form B.

17. For the sake of uniformity, the first oscillation in the case of

rolling is to be from port to starboard; and in the case of heeling from port to less port, or starboard to more starboard, or, in other words, from left to right, if the observer is facing forward.

Rolling.

To fill up Columns *b* and *g* :—

The sum of the entries in Columns *d* and *e*, connected by the ***horizontal*** portions of the zigzag, must be entered in Column *g*; and of those connected by the ***oblique*** portions of the zigzag in Column *b*.

The "*Number of oscillations in five minutes*" is the number printed in Columns *a* or *h*, opposite to which the last observation is recorded.

The "*Number of oscillations in one minute*" is found by dividing the preceding number by 5.

The "*Mean number of degrees in each oscillation*" is found by adding together the sum of the entries in Columns *b* and *g*, and dividing this by the number of oscillations.

The "*Mean angle of oscillation* from starboard to port" is found by dividing the sum of the entries in Column *b*, which are the oscillations from starboard to port, by the number of entries.

The "*Mean angle of oscillation* from port to starboard" is found by dividing the sum of the entries in Column *g*, which are the oscillations from port to starboard, by the number of entries.

"Angle of Inclination from Vertical."

The "*Mean angle to port*" is found by dividing the sum of the entries in Column *d* by the number of entries in the same column.

The "*Mean angle to starboard*" is found in the same manner from Column *e*.

The "*Maximum angle to port*" is the largest recorded angle in Column *d*.

The "*Maximum angle to starboard*" is the largest recorded angle in Column *e*.

The "*Minimum angle to port or starboard*" is the smallest recorded observation in Columns *d* and *e* respectively.

Heeling.

To fill up Columns *b* and *g* :—

The difference of the entries connected by the horizontal portion of the zigzag is to be entered in Column *g*; and of those connected by the oblique portion in Column *b*.

The "*Number of oscillations* in five minutes and one minute" respectively, is found as for rolling. (*See* above).

The "*Mean angle of oscillation* from starboard to less starboard," or from "port to more port," is found by dividing the sum of entries in Column *b* by the number of entries in the same column.

The "*Mean angle of oscillation* from port to less port," or from "star-

board to more starboard," is found by proceeding in the same manner with Column *g*.

"Angle of Inclination from Vertical."

The *"Mean of extreme angles to starboard"* is found by dividing the sum of the entries in Column *f* by the number of entries in the same column.

The *"Mean of extreme angles to port"* is found after the same method from Column *c*.

The *"Mean of inferior angles to starboard"* is found in a similar manner from Column *e*; and of *"Inferior angles to port"* from Column *d*.

The *"Maximum of extreme angles to starboard"* or of *"Extreme angles to port,"* is the HIGHEST entry in Columns *f* or *c* respectively.

The *"Maximum of inferior angles to starboard,"* or of *"Inferior angles to port,"* is the HIGHEST entry in Columns *e* or *d* respectively.

The *"Minimum of extreme angles to starboard,"* or of *"Extreme angles to port,"* is the LOWEST entry in Columns *f* or *c* respectively.

The *"Minimum of inferior angles to starboard,"* or of *"Inferior angles to port,"* is the LOWEST entry in Columns *e* or *d* respectively.

Captain JASPER SELWYN, R.N.: I would ask Admiral Ryder one question. Is there any correction applied in considering the effect on the observation-battens due to the fact that the observer is not at the centre of motion?

Admiral RYDER: None is necessary. It is not necessary that the eye should be at the centre of motion, but the pendulum should be there if its motion is recorded.

Captain SELWYN: You will find there will be a correction necessary when the ship is raised by a wave.

Commander GILMORE, R.N.: You take the plane of the ship as regards the batten.

Admiral RYDER: When you mark the batten in harbour or in a quiet sea, you place the zero point in line with the horizon; it introduces no error of any importance. The dip of the horizon is about five minutes on the bridge of an ironclad. If the ship is raised by the sea 30 feet, the dip would be about 10 minutes, introducing an error of no importance, as we don't profess to observe the heel nearer than half a degree, or 30 minutes.

CHAIRMAN: We have to thank Admiral Ryder for his interesting and valuable communication.

APPENDIX.

Example 1. Form A.—Form for Noting Heels and Rolls by the Vertical Battens.

H.M.S.

ROLLING.

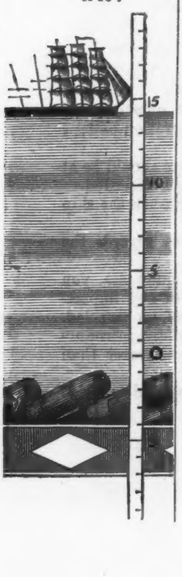
Oscillation.
- Number of in — Min. 5...... Min. 1......
- Mean No. of Degrees in each.
- Mean angl of from — Starbd to Prt; Prt to Starbd

Angle of Inclination from Vertical.
- Mean to — Port; Starbd.
- Max. to — Port; Starbd.
- Min. to — Port; Starbd.

Largest oscillation
Smallest ditto

Port Batten.

Showing an angle of inclination to Port of 14°.



	Date				Hour			
No. of Oscillation.	Complete Angle of Single Oscillation.	Angle of Inclination. Ship lists to P	P		Angle of Inclination. Ship lists to S	S	Complete Angle of Single Oscillation.	No. of Oscillation.
a.	b.	c.	d.		e.	f.	g.	h.
								1
2								3
4								5
6								7
8								9
10								11
12								13
14								15
16								17
18								19
20								21
22								23
24								25
26								27
28								29
30								31
32								33
34								35
36								37
38								39
40								41
42								43
44								45
46								47
48								49
50								51
52								53
54								55
56								57
58								59
60								61
62								63
64								65

HEELING.

Oscillations.
- Number of in — Min. 3........ Min. 5........
- Mean No. of Degrees in each
- Mean Angle of from — Starbd. to less Starbd.; Port to more Port; Port to less Port; Starbd. to more Starbd.

Angle of Inclination from Vertical.
- Mean of — Extreme Angles to Starboard or Port; Inferior Angles to Starboard or Port
- Maximum of — Extreme Angles to Starboard or Port; Inferior Angles to Starboard or Port
- Minimum of — Extreme Angles to Starboard or Port; Inferior Angles to Starboard or Port

Largest oscillation ......
Smallest ditto ......

Example 2. *Note.—The following is the record of an observation when the ship was heeling.*

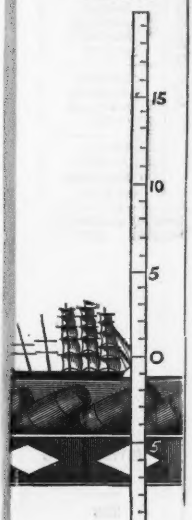
Form A. Form for Noting Heels and Rolls by the Vertical Battens, H.M.S. "Bellerophon."

ROLLING.

Oscillation.	Number of in	Min. 5	
		Min. 1	
	Mean No. of Degrees in each		
	Mean angl. of from	Starbd to Prt	
		Prt to Starbd	
Angle of Inclination from vertical.	Mean to	Port	
		Strbd.	
	Max. to	Port	
		Strbd.	
	Min. to	Port	
		Strbd.	

Greatest oscillation
Smallest oscillation

Port Batten.
Showing an angle of inclination to Starboard of 1°.



Date, June 29, 1869.					*Hour*, 11 a.m.			
No. of Oscillation.	Complete Angle of Single Oscillation.	Angle of Inclination. Ship lists to P	P		Angle of Inclination. Ship lists to S	S	Complete Angle of Single Oscillation.	No. of Oscillation.
a.	*b.*	*c.*	*d.*		*e.*	*f.*	*g.*	*h.*
					3·5	4·0	0·5	1
2	0·5				3·5	4·2	0·7	3
4	1·2				3·0	4·0	1·0	5
6	1·0				3·0	4·5	1·5	7
8	1·7				2·8	3·5	0·7	9
10	1·0				2·5*	3·2*	0·7	11
12	1·2				3·0	3·5	0·5	13
14	1·0				2·5	5·0	2·5	15
16	1·0				4·0*	6·0	2·0	17
18	3·0				3·0	6·2*	3·2*	19
20	2·7				3·5	5·0	1·5	21
22	2·0				3·0	4·2	1·2	23
24	1·2				3·0	4·0	1·0	25
26	1·5				2·5	3·5	1·0	27
28	0·7				2·8	3·5	0·7	29
30	0·5				3·0	4·2	1·2	31
32	0·2*				4·0	5·0	1·0	33
34	2·0				3·0	4·5	1·5	35
36	1·0				3·5	4·2	0·7	37
38	1·0				3·2	4·0	0·8	39
40								41
42								43
44								45
46								47
48								49
50								51
52								53
54								55
56								57
58								59
60								61
62								63
64								65
	19)24·4				20)62·3	20)86·2	20)23·9	
	1°·3′				3°·1	4°·3	1°·2	

HEELING,

Oscillations.	Number of in	Min. 5	39
		Min. 1	7·8
	Mean No. of Degrees in each		1°·2
	Mean Angle of from	Starbd. to less Starbd.	1°·3
		Port to more Port	
		Port to less Port	
		Starbd. to more Starbd.	1°·2
Angle of Inclination from Vertical	Mean of	Extreme Angles to Starboard or Port.	4°·3
		Inferior Angles to Starboard or Port.	3°·1
	Maximum of	Extreme Angles to Starboard or Port.	6°·2
		Inferior Angles to Starboard or Port.	4°·0
	Minimum of	Extreme Angles to Starboard or Port.	3°·2
		Inferior Angles to Starboard or Port.	2°·5

Largest oscillation...... 3°·2
Smallest oscillation...... 0°·2

24·4
23·9
39)41·3(1°·2′

EXAMPLE 3. *The following is the record of an observation when the ship was rolling.*

FORM A. FORM FOR NOTING HEELS AND ROLLS BY THE VERTICAL BATTENS.

H.M.S. "PENELOPE."

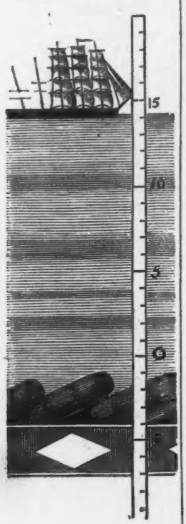
ROLLING.

Oscillation.	Number of in	Min. 5 ...	43
		Min. 1......	8·6
	Mean No. of Degrees in each		17·6
	Mean angl of from	Starbd to Prt	18
		Prt to Starbd	17·3
Angle of Inclination from Vertical.	Mean to	Port	11·1
		Starbd.	6·2
	Max. to	Port	19·5
		Starbd.	14·0
	Min. to	Port	4·5
		Starbd.	0·5

Greatest oscillation ... 33½
Smallest ditto ... 5½

PORT BATTEN.

Showing an angle of inclination to Port of 14°.



Date, January 29, 1869.				Hour, 4 P.M.			
No. of Oscillation.	Complete Angle of Single Oscillation.	Angle of Inclination. Ship lists to P	P	Angle or Inclination. Ship lists to S	S	Complete Angle of Single Oscillation.	No. of Oscillation.
a.	b.	c.	d.	e.	f.	g.	h.
			11½	6		17½	1
2	17½		11½	5½		17	3
4	13½		8	4		12	5
6	12½		8½	5½		14	7
8	13		7½	3½		11	9
10	14½		11	8		19	11
12	26		18	11		29	13
14	30½		19½*	14*		33½*	15
16	33		19	11½		30½	17
18	23½		12	5½		17½	19
20	18		12½	7½		20	21
22	17		9½	5½		15	23
24	14½		9	5		14	25
26	15½		10½	5		15½	27
28	15		10	4½		14½	29
30	12		7½	0½*		8	31
32	7½		7	6		13	33
34	18½		12½	6½		19	35
36	18½		12	9½		21½	37
38	24½		15	8		23	39
40	16		8	2½		10½	41
42	7		4½*	1		5½*	43
44							45
46							47
48							49
50							51
52							53
54							55
56							57
58							59
60							61
62							63
64							65
	21)378		22)244½	22)136		22)380½	
	18		11·1	6·2		17·3	

HEELING.

Oscillations.	Number of in	Min. 5.........	
		Min. 1.........	
	Mean No. of Degrees in each		
	Mean angle of from	Starbd. to less Starbd.	
		Port to more Port	
		Port to less Port	
		Starbd. to more Starbd.	
Angle of Inclination from Vertical	Mean of	Extreme Angles to Starboard or Port	
		Inferior Angles to Starboard or Port	
	Maximum of	Extreme Angles to Starboard or Port	
		Inferior Angles to Starboard or Port	
	Minimum of	Extreme Angles to Starboard or Port	
		Inferior Angles to Starboard or Port	

Greatest oscillation...
Smallest ditto ...

378
380½
43)758½(17·6
43
328

......

......

h

d.

n...

...

17·6

APPENDI

Form B.

FORM of Return of Rolling, Heeling, and Pe

Date.	On Board. Provisions.	On Board. Stores.	On Board. Coals.	Draft of Water as nearly as can be ascertained. Forward.		Aft.		Time of Taking and Recording Observations.		Rolling Motion ascertained from Five Minutes Observations of the Battens. Rolling. Oscillations. Number of Oscillations in		Mean number of Degrees in each Oscillation.	Mean angle of Oscillation from Starboard to Port.	Port to Starboard.	Angle of Inclination from Verti… Mean angle to Port.	Starboard.	Maximum angle to Port.	Starboard.	Minimu… angle t… Port.	Starboard…
	Days.	Months.	Tons.	Ft.	In.	Ft.	In.	H.	M.	Mins. 5	Min. 1	°	°	°	°	°	°	°	°	°
Jan. 7	4	6	380	25	2	26	4	P.M. 4		43	8·6	17·6	18	17·3	11·1	6·2	19·5	14·0	4·5	0
March 8	2	4	220					P.M 5												
June 29	1	3	170					A.M. 11												

PENDIX.

and Performance at Sea of Her Majesty's Ship

…s. from Vertical.	Minimum angle to		When Ship is Heeling and Rolling to Windward of Perpendicular, only doing so occasionally, Heel ascertained by Five Minutes Observations of the Battens. Heeling. Oscillations. Number of Oscillations in							Angle of Inclination from Vertical. Mean of				Maximum of				Minimum of			
					Mean number of Degrees in each Oscillation.	Mean angle of Oscillation from				Extreme angles to		Inferior angles to		Extreme angles to		Inferior angles to		Extreme angles to		Inferior angles to	
	Port.	Starboard.	Mins. 5	Min. 1		Starboard to less Starboard.	Port to more Port	Port to less Port.	Starboard to more Starboard.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.
	°	°			°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	4·5	0·5																			
			53	10·4	14·0	14			13·0	13·2		1·9		24		4½	12	9		0	0
			39	7·8	1·2	1·3			1·2	4·3		3·1		6·2		4		3·2		2·5	

Angle of Inclination

EXAMPLE 4. *Note.—The following is the record of an observation when the ship was heeling, but occasionally rolling to windward.*

FORM A. FORM FOR NOTING HEELS AND ROLLS BY THE VERTICAL BATTENS.

H.M.S. "PENELOPE."

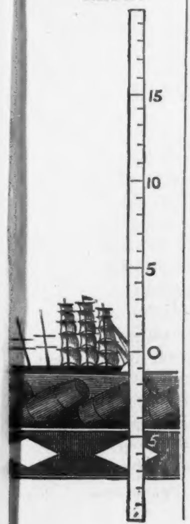
Date, March 8, 1869. *Hour*, 5 P.M.

ROLLING.

Oscillation.	Number of in	Min. 5.....
		Min. 1......
	Mean No. of Degrees in each.	
	Mean angl of from	Starbd to Prt
		Starbd to Prt
Angle of Inclination from Vertical.	Mean to	Port
		Starbd
	Max. to	Port
		Starbd
	Min. to	Port
		Starbd
Greatest oscillation...		
Smallest ditto ...		

PORT BATTEN.

Showing an angle of inclination to Starboard of 1°



No. of Oscillation.	Complete Angle of Single Oscillation.	Angle of Inclination. Ship lists to P		Angle of Inclination. Ship lists to S		Complete Angle of Single Oscillation.	No. of Oscillation.
a.	b.	c.	d.	e.	f.	g.	h.
				2	13	11	1
2	16		3		18½	21½	3
4	22½		4		13½	17½	5
6	13½		0		11	11	7
8	9			2	14	12	9
10	16		2		15½	17½	11
12	14½			1	9	8	13
14	7			2	13	11	15
16	10½			2½	10	7½	17
18	5½			4½*	10	5½*	19
20	7½			2½	14	11½	21
22	16½		2½		17½	20	23
24	24½		7		24*	31	25
26	36*		12*		21	33*	27
28	27		6		13½	19½	29
30	18		4½		16½	21	31
32	20½		4		13	17	33
34	13		0		10½	10½	35
36	9			1½	12	10½	37
38	11			1	9½	8½	39
40	7½			2	12	10	41
42	11			1	9*	8	43
44	8			1	10½	9½	45
46	10½			0*	11	11	47
48	8			3	9	6	49
50	8			1	13	12	51
52	14½		1½				53
54							55
56							57
58							59
60							61
62							63
64							65
	26)365		12)46½	15)27	26)343½	26)361½	
	14		3·9	1·9	13·2	13·9	

HEELING.

Oscillations.	Number of in	Min. 5.........	52
		Min. 1.........	10·4
	Mean No. of Degrees in each.		14°·0
	Mean Angle of from	Starbd. to less Starbd.	14°·0
		Port to more Port	
		Port to less Port	
		Starbd. to more Starbd.	13°·0
Angle of Inclination from Vertical.	Mean of	Extreme Angles to Starboard or Port	13°·2
		Inferior Angles to Starboard or Port	1°·9 3°·9
	Maximum of	Extreme Angles to Starboard or Port	24°·0
		Inferior Angles to Starboard or Port	4°·½ 12°·0
	Minimum of	Extreme Angles to Starboard or Port	9°
		Inferior Angles to Starboard or Port	0 0

Largest oscillation ...... 36°
Smallest ditto 5½

361½
365
52)726½(
14

LECTURE.

Friday, January 20th, 1871

Lieut.-Colonel T. St. LEGER ALCOCK, Vice-President, in the Chair.

THE RED RIVER EXPEDITION.

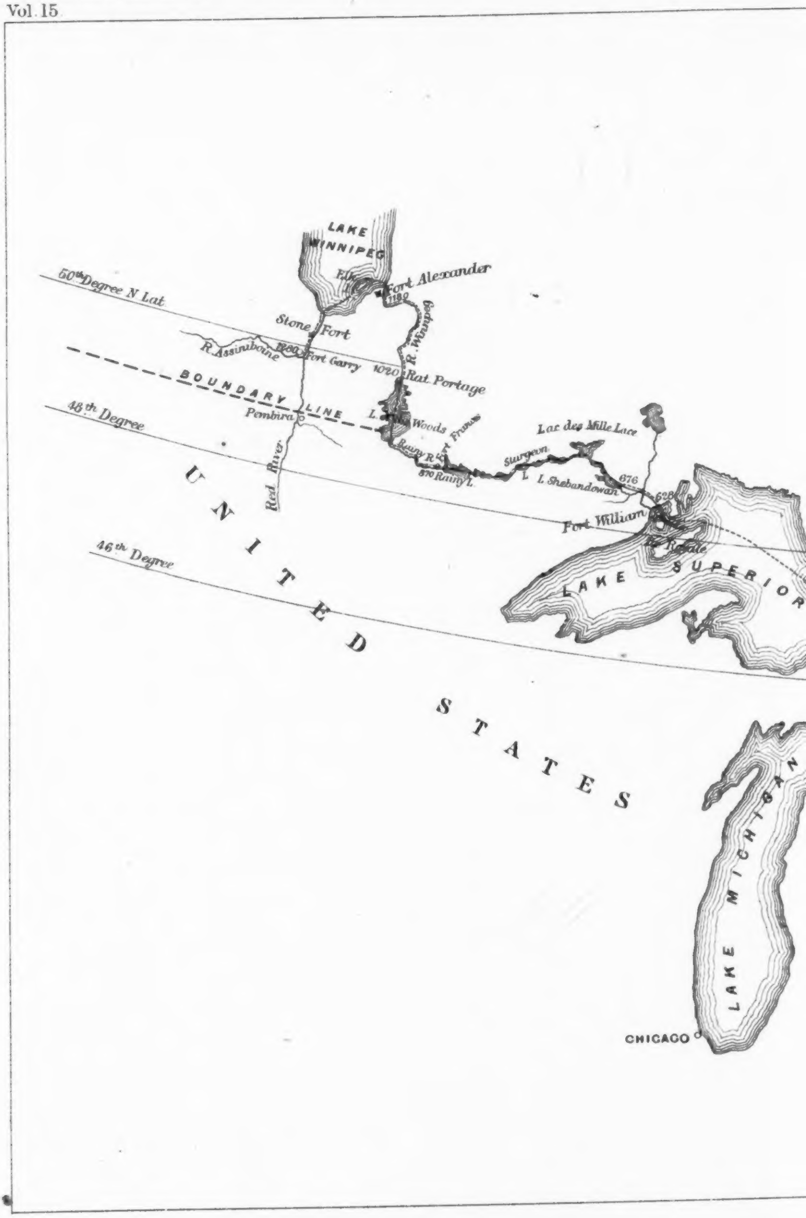
By Captain G. L. Huyshe, Rifle Brigade.

As the story of the Red River Expedition is now being told in the pages of "Blackwood's Magazine," and as a work is about to appear from the pen of one who took part in the long dreary advance for 600 miles through the wilderness which separates "Fort Garry" from the civilized world, I shall confine myself to describing the purely military features of the operations. Any one who is desirous of more detailed information than I can give in this short lecture, will find it in the work above alluded to.

Political and Geographical Outline of the Red River Territory.

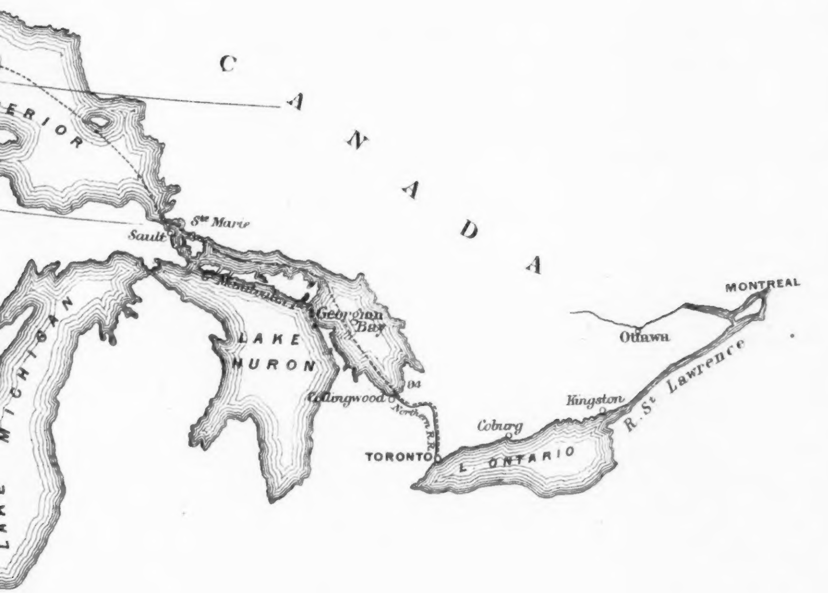
Without attempting to go very deeply into the causes of the rebellion, I think I ought to give you a brief outline of the geography of the Red River Territory, or rather of the inhabited portion of it.

The 49th parallel of latitude from the "Lake of the Woods" westward to the "Rocky Mountains," forms the boundary between the British possessions in North America and the United States. The Red River flowing northward, crosses that artificially-defined frontier at about the 97th meridian of west longitude. "Fort Garry" on the left bank of that river, where it is joined by the Assiniboine, is 60 miles from the frontier, they being in about the same latitude as Amiens, or Frankfort. From thence to the nearest railway or telegraph station in the United States is 600 miles, and to the nearest station in Canada about 900 miles, in a straight line. Its geographical position has, therefore, completely isolated it from the outside world and from civilization. It cost much more than the ordinary emigrant could usually afford to get there. Even supposing him to have done so, and to have established himself on a farm, there was no internal market for his produce, in a country where every one was an agriculturist, and grew enough wheat, &c., for his own consumption, and great distances


LAKE WINNIPEG
Fort Alexander
50th Degree N Lat
Stone Fort
R. Assiniboine
Fort Garry
R. Winnipeg
1020 Rat Portage
BOUNDARY LINE
Pembina
48th Degree
Woods
Rainy R.
870 Rainy L.
Sturgeon
Lac des Mille Lacs
L. Shebandowan
676
Red River
Fort William
46th Degree
UNITED STATES
LAKE SUPERIOR
LAKE MICHIGAN
CHICAGO

ROUTE
of the
RED RIVER EXPEDITIONARY FORCE
from
TORONTO TO FORT GARRY

The figures represent the distances in Miles from Toronto.



J. Jobbins

intervening between him and the nearest towns or railways, precluded all idea of his selling his corn elsewhere.

The inhabited part of the Red River Territory, now included in the province of Maintoba, is merely the portion lying along the banks of the Red River, and of its affluent, the Assiniboine; except at some small out-lying settlements, all the farms abut upon either of those rivers. The number of inhabitants at the beginning of 1870 was supposed to be about 15,000, exclusive of Indians. A large proportion consisted of half-breeds, descended from French-Canadian fathers and Indian mothers, so that French was the language spoken by at least half the people. In religion they were tolerably evenly divided between Protestants and Roman Catholics.

The Hudson's Bay Company claimed an undisputed right over the territory in virtue of a Charter received from King Charles II. After a lengthened negotiation, the Government of Canada agreed to pay £300,000 to the Company as compensation for the surrender of all territorial rights claimed by it. A Lieutenant-Governor was appointed to rule over the province before even the transfer had been announced by Royal Proclamation, and he was sent there, viâ the United States, in the month of October, 1869.

Causes of the Rebellion.

There appears to have been a good deal of mis-management on the part of the Canadian Government in these arrangements. The feelings, wishes, and prejudices of the people were so entirely ignored that a few designing men, backed up by priestly influence, were enabled, with a considerable show of justice on their side, to stir up the French half-breeds to rebellion, so that at last, under the leadership of a man named "Louis Riel," the disaffected party were strong enough to prevent the entrance of the Lieutenant-Governor into the territory. The English-speaking people were quite as discontented as their French neighbours with the off-hand manner in which Canada had tried to treat them, but they were at heart too loyal to Her Majesty, and too fond of British institutions to assist a band of men leagued together for an unlawful purpose, and who were in fact simply rebels.

The Canadian Government, appreciating the errors they had committed, made every effort to retrieve them. They conceded everything that could in fairness be claimed, and despatched Commissioners to arrange details, and smooth down difficulties. All these efforts failed, for "Riel," having made himself master, and seized upon the stores of the Hudson's Bay Company, with which he paid and fed his men, did not feel inclined to descend from the position he had assumed. He held "Fort Garry" with a body of armed men, hauled down the British flag and hoisted in place of it a flag of his own, rather a pretty one, by the way, of fleurs de lis and shamrocks, a compound of French and Fenianism, and was in open treaty with fillibustering Yankee-Fenians for the transfer of the country to the United States. Meantime he ruled the settlement in a most despotic manner, imprisoning and rob-

bing whom he wished, and at last went so far as to arraign before a mock court-martial one of the loyal Canadians, a man named "Scott," whom he had tried on some frivolous charge, and shot the same day with barbarous and inhuman cruelty.

The Government of Canada, being convinced that there were only two courses open to it, either to abandon the country altogether, or to send an army to take possession of it, to drive away Riel and restore the Queen's authority, wisely determined on the latter course. The proposal met with the approval of the Home Government, who agreed to allow a proportion of Imperial troops to be employed on this service in conjunction with Canadian militia. Steps were accordingly taken for organizing the expedition, under the superintendence of Lieut.-General the Hon. James Lindsay, the then Commander-in-Chief in Canada, who nominated Colonel, now Sir Garnet, Wolseley, at that time Deputy Quartermaster-General in Canada, to the command.

Selection of Route for Expedition.

There were only two routes by which British troops could reach Fort Garry, one by landing at York Factory in Hudson's Bay, and ascending the Nelson River to Lake Winnipeg; the other by landing at Thunder Bay on Lake Superior, and following a canoe route through rivers and lakes, and over numerous "portages," for a distance of upwards of 600 miles. This distance was capable of being shortened by 150 miles, if it were possible to march from the north-west angle of Lake of the Woods to Fort Garry, by a road that was partly made.

As the word "portage" will occur frequently in this lecture, it will be as well to explain at once that it means a break in the navigation between two lakes, or between a river and a lake, etc.; over this break everything has to be "portaged" or carried on men's backs. Some of the portages we passed were nearly two miles long.

The first-named route, that by York Factory, was the one that had been hitherto made use of in the conveyance of small bodies of troops, which had been once or twice previously quartered at "Fort Garry;" but these had never exceeded a few hundred in number, and had entered the country when everything was in a state of peace, and when the whole resources of the Hudson's Bay Company could be brought into play to transport them to their destination. Their boats, stores, provisions, &c., had been sent from Fort Garry for their use during their journey up from York Factory. We had to take ours with us. Again, to have sent any large body of men from Canada by that route, would have been most difficult. The navigation through the frozen waters of the Arctic Ocean is both difficult and dangerous, and the sea off York Factory is only free from ice for about six weeks in the year. The second route was therefore adopted.

Construction of Boats.

Over this route nothing larger than birch-bark canoes had ever passed; but it would have been impossible to have obtained these in

sufficient numbers, and, if obtained, their carrying capacity would not have been sufficient for our purposes; besides which, skill at the paddle requires long practice, whereas the soldier soon learns to pull an oar. It was therefore necessary to construct boats especially for the expedition, and in this considerable judgment was requisite. This duty was entrusted to Mr. Dawson, the able executive Officer of the Public Works Department, who during his numerous explorations of wild countries had had great experience in navigating rapid and shallow rivers. He laid down general principles as to length, breadth, &c., leaving the working out of the design to the several boat-builders employed. The boats, therefore, differed considerably in size and shape, but on an average may be said to have been from 25 to 30 feet long, from 6 to 7 broad, with a draught when loaded of from 24 to 30 inches, and a carrying capacity of $2\frac{1}{2}$ to 4 tons. Each boat was intended to carry 10 soldiers and 4 boatmen, with 30 days' provisions for its crew, besides ammunition and stores of various sorts. Mr. Dawson also undertook the raising of a body of *voyageurs* or skilled boatmen to navigate the boats. It was originally intended that there should be four of these voyageurs in each boat, but Colonel Wolseley ultimately reduced the number to two, which number was found amply sufficient. A proportion of these voyageurs were "Iroquois Indians," who were found to be splendid fellows, and without whom it is not too much to say, the expedition never would have reached its destination; of the others, many were indifferent, and had to be carefully weeded. I shall not give a detail of the articles which it was proposed should be carried in the boats in the original scheme of organization, as it was subsequently altered, owing to unavoidable delays; but attached to this lecture will be a return showing the exact amount of everything that was actually embarked at "Shebandowan Lake" by the first eleven brigades of boats. The time at our disposal was so much reduced, that Colonel Wolseley had to abandon the idea of forming a depôt of supplies at "Fort Frances," before the troops advanced beyond that point, and was obliged to content himself by reducing the number of men in each boat, so as to admit of 60 days' provisions being taken instead of 30. It was hoped that 40 days actually *en voyage* would take us to Fort Garry, thereby leaving a large margin to provide against losses, and the contingency which we had always to keep uppermost in our minds, viz., that of having to fight for he possession of the country when we got there.

Composition and Organization of the Force.

The strength of the expeditionary force was, after much consideration, fixed at one battalion of regular Infantry, two batallions of Canadian Militia, a detachment of Royal Engineers, and another of Royal Artillery, with a battery of four 7-pounder mountain guns; also a proportion of the Army Service and Army Hospital Corps. The two regiments of Canadian Militia were raised and organized under the superintendence of Colonel Feilden of the 60th Rifles, at Toronto, where the force may be said to have made its rendezvous previous to start-

ing for Thunder Bay. The strength of the companies was fixed at 50 men, including 3 Officers, and the number of companies per battalion was 7. To each was assigned a brigade of 6 boats, each brigade being distinguished by the letters of the alphabet A, B, C, &c., &c.

Equipment of Officers.

The Officers were armed with breech-loading carbines, or short Sniders, in lieu of swords, which being considered a useless incumbrance in the boats, were ordered to be left behind. The amount of baggage allowed for each Officer, without distinction of rank, was fixed at 90 lbs., to include cooking utensils, bedding, &c., and this order was rigidly enforced. Attached to this lecture are returns showing the special clothing that each soldier was provided with, and the scale of daily rations laid down.

Rations and Clothing.

This scale had been framed, after much careful consideration, upon the allowance granted to the North American Lumber-men, who perform the hardest possible labour during the extreme cold of a Canadian winter; so, although it was an unheard-of thing in our Army to send off an expedition into a wilderness for five months without any spirits, still, as the backwoods-man was able to do hard work without spirits, it was rightly thought that the British soldier could do the same. The men were allowed a large daily ration of tea, 1 oz. per man. practically as much as they could drink; and as I am now on this subject of "Bohea" *versus* "Grog," I may as well state that the experiment was *most* successful. The men of no previous expedition have ever been called upon to perform harder or more continuous labour for over four months, and I think it may be confidently asserted that no troops have at any time acquitted themselves with greater credit: they were always cheery, and worked with a zealous will that could not be surpassed. This expedition would have been a bright era in our military annals had it had no other result than that of proving the fallacy hitherto believed in of the necessity of providing our men when in the field with intoxicating liquors. Everyone who has been on active service knows the trouble that guarding rum always entails, and the many irregularities and courts-martial that its presence produces. In the Red River expedition there was no sickness and no crime.

Land Transport Corps.

For the carriage of the boats, stores, &c., from Thunder Bay to Lake Shebandowan, the Militia Department raised a Land Transport Corps, which consisted of 150 horses, about half that number of teamsters, and a number of waggons and carts, also about 16 span of draught oxen. The harness provided by the Militia Department was of inferior quality and the collars were too small, consequently many of the horses, owing to galled shoulders, speedily became unfit for work. I may mention here as a fact worthy of being remembered in the future

organization of a Transport Service consisting of draught cattle, that about 20 per cent. of spare breast-gear should always be provided to supplement the collar harness. Thus, when a horse shows symptoms of galled shoulders he can be worked with the breast-harness, and *vice versâ.* In America breast-draught is very common, many people preferring it to collar-draught; I believe it is also used in the French artillery.

To protect the men from the attacks of flies they were served out with veils of fine black netting, secured round the head and throat by elastic bands and kept off the face by wire hoops, similar to those used in children's crinolines. Cans of mosquito oil, a disagreeable compound of oil and penny-royal, were also provided to smear over the hands and face. For the men's rifles and side-arms, arm-chests were made to fit the boats; and these and other details, such as waterproof kit-bags, mocassins, &c., too numerous to mention in the short limits of this lecture, had all to be thought of and provided before hand. In fact, for the organization of this little force the utmost possible care and forethought were necessary, and multitudinous details required for the special nature of the operations and for the four different species of transport, viz., railway, steamer, land carriage, and boats, engaged the attention of the authorities.

The Mountain Battery.

When the expedition had been first determined upon, the Canadian Ministry had telegraphed to England for a battery of Abyssinian steel guns. I do not know the reason, but a battery of bronze guns was sent out instead. These guns weighed about 50 lbs. more than the steel guns used in Abyssinia, and as no "*range tables*" had been sent with them, Colonel Wolseley considered it advisable to fire a few rounds from them before we left Thunder Bay. Fortunate it was indeed that this was done. After the third or fourth round one of the carriages became unserviceable, and after close examination was found to have been made of perished wood, which had evidently been an old carriage of one of the guns of Her Majesty's ship "Terrible," for the old bolt-holes could be seen plugged up with putty and the letters "*errible*" were clearly made out. The iron-work, too, was of very inferior metal, and gave way in several places. But, for the omission of the range tables, these defects would not have been found out, and might have been productive of the most serious consequences. The neglect to send the range tables *may* admit of explanation, but to send out of Woolwich Arsenal a worthless gun-carriage made of perished wood and inferior metal is an error of a different nature, which must be left for explanation to the proper authorities.

Proposed Plan of Operations.

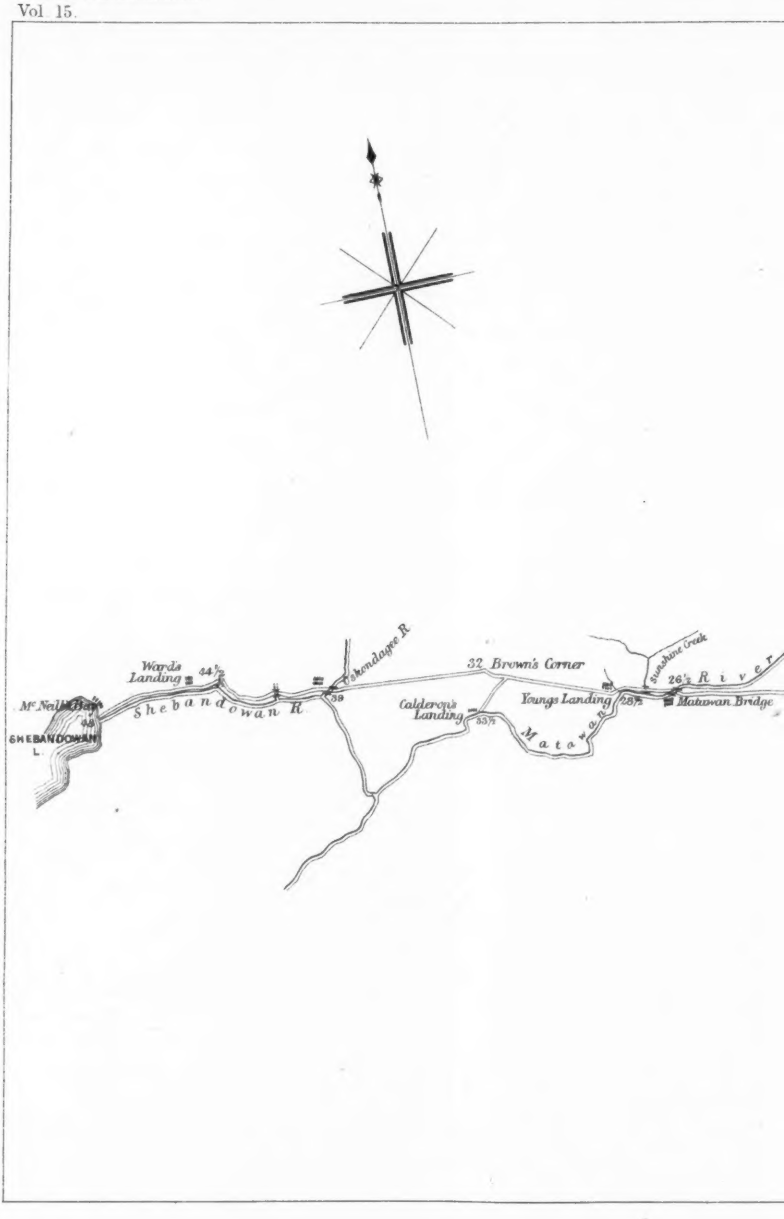
The proposed plan of operations was to convey the troops from Toronto to Collingwood (94 miles) by rail, thence in steamers across Lakes Huron and Superior to Thunder Bay (524 miles); thence by road

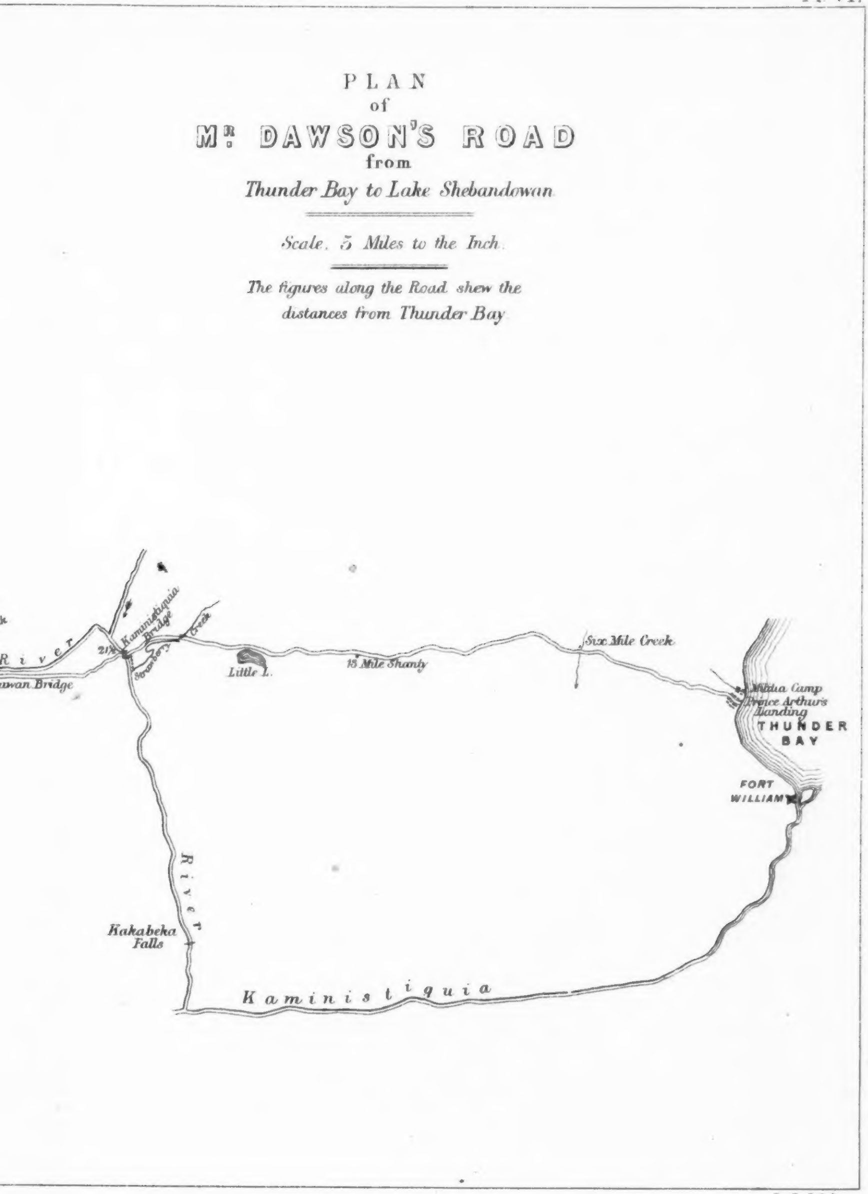
(48 miles) to Lake Shebandowan, where the final embarkation in the boats would take place, and the troops would force their way through the network of lakes and rivers, extending in an almost unbroken chain to Fort Garry, 550 miles further, the whole distance from Toronto being upwards of 1,200 miles. It was proposed to establish a large depôt of supplies and a hospital at Thunder Bay, which would thus become the base of operations; to construct a defensive work there for its protection, and to leave a company of Militia in garrison there, when the force advanced. These precautions were deemed necessary, as the Fenians had avowed their intention of making a descent on the place, and burning the hospital and stores left behind after the force had advanced. A depôt of supplies and a hospital was also to have been formed at Fort Frances, about half way between Lake Superior and Red River. The force was expected to land at Thunder Bay as early as possible in May, to march by road to Shebandowan Lake, embark there, and make the best of its way to Fort Frances, where it was to "rendezvous," previous to advancing upon Fort Garry. The latter end of July it was expected would see the arrival of the expedition at Fort Garry. The rebel government was to be overthrown, and Her Majesty's authority restored; the two battalions of Canadian Militia and the guns were to be left to garrison the country, whilst the regular troops were to return to Canada by the same route, before the winter frosts had set in. This was the plan of operations decided on at Ottawa.

Closing of the Sault Ste. Marie Canal.

The ice on Lake Superior generally breaks up in the first week of May; it was therefore hoped that we should have been able to have sailed about the 8th or 9th of that month, but owing in great measure to the dilatory inaptitude for military affairs displayed by the Canadian Ministry, the first detachment did not sail from Collingwood until the 21st.

Lakes Huron and Superior are united by the Ste. Marie River, on which there are very fine rapids, caused by the difference of level between the two lakes, so that vessels have to pass through a canal, in order to get from one to the other. Unfortunately that canal runs exclusively through American territory, and in a most unfriendly spirit it was closed to our shipping by the Commandant at Fort Brady, as soon as it was found that it was required for the purposes of the expedition. After some diplomatic correspondence between the Government of the Dominion and the Washington Cabinet, the embargo was withdrawn, and our vessels were allowed to pass through the canal, provided they had no warlike *matériel* on board. In the meantime, however, Colonel Wolseley had dispatched four companies of Militia to the Canadian side of the rapids, together with a small portion of the Land Transport; and the vessels that were refused a passage through the canal were unloaded at the foot of the rapids, and their cargoes carried across the "portage" (3 miles) to the head of the rapids, where they were re-embarked on Lake Superior. This duty was entrusted to Lieutenant-Colonel Bolton, the Deputy-Assistant Adjutant-General of


Ward's Landing
44½
Oskondagee R
32 Brown's Corner
Sunshine Creek
26½ River
Mc Neill's Bay
48
SHEBANDOWAN L.
Shebandowan R.
38
Calderon's Landing
33½
Youngs Landing
28½
Matowan Bridge
Matawan


PLAN
of
MR. DAWSON'S ROAD
from
Thunder Bay to Lake Shebandowan
Scale, 5 Miles to the Inch.
The figures along the Road shew the
distances from Thunder Bay
Kaministiquia Bridge
21½
Little L.
15 Mile Shanty
Six Mile Creek
Militia Camp
Prince Arthur's Landing
THUNDER BAY
FORT WILLIAM
River
River
Kakabeka Falls
Kaministiquia

J. Jobbins

the Force, who remained at the Sault Ste. Marie for upwards of a month, until the whole of the troops and stores had passed through.

Embarkation and Landing at Thunder Bay.

It was on the 25th of May that the first detachment landed in Thunder Bay, at a point where the road to Lake Shebandowan commenced. Colonel Wolseley named this place "Prince Arthur's Landing," in honour of His Royal Highness, who was then doing duty with his battalion of the Rifle Brigade in Canada.

And now began the hard work. From early dawn to late at night everybody was at work in our miniature Balaclava, unloading the steamers, or labouring at the redoubt or on the road. Owing to the shallowness of the water at the landing-place, steamers had to lie off about a quarter of a mile from shore. Fortunately we had a large flat-bottomed scow, 55 feet long by 14 broad, drawing only 2 feet of water when loaded, and capable of carrying 50 tons. This scow was towed backwards and forwards from the wharf to the steamers by a tug, and everything was landed in this way. The scow was also found very useful for landing the horses, which were led out of the steamers on to the deck of the scow, 20 at a time, and landed in the same way without difficulty, and without a single accident.

Difficulties of the Road.

But the road was our great obstacle, and caused a long and tedious delay. When at Ottawa, Colonel Wolseley had been assured by Mr. Dawson, the engineer in charge of its construction, that it would be open for traffic by the 25th of May, but on that date only 30 miles were made, and there remained 18 more almost untouched.

However we had to make the best of it; strong parties of soldiers were put on it, and the work pushed forward vigorously. The road passes at first over a sandy district, then over rugged hills thickly wooded, with numerous intervening swamps; then comes red clay of the most sticky nature, and quite impervious to water. In fine dry weather the surface was soon baked hard as a brick by the sun, but after the first shower of rain it became like soap, and so slippery, that the horses had great difficulty in keeping their feet. After heavy rain it became dreadfully cut up, and impracticable for wheeled transport to such an extent, that on many occasions we had to stop all traffic over it for days together, as our horses became unfit for work in great numbers, from exhaustion and galled shoulders. We had no time to break our horses into work by degrees, but had to work them hard the day after they landed. They arrived fat, after the long rest of a Canadian winter, and consequently were in no condition for hard and continuous work. But time was of such importance to us, that we could not afford to be humane; we were prepared to sacrifice all the draught cattle provided we could get the last barrel of pork required taken to the end of the road by the last horse, before he died. When the bullocks became unfit for work, they were killed and eaten.

These thickly wooded districts are very subject to the ravages of fire; during the seven or eight weeks that we were occupied in getting over this forty-eight miles of road, two tremendous fires swept over the country, doing a great deal of damage to the road, burning fascine and cribwork, culverts, &c., and in one instance destroying the camp of one of the working parties. The road passes over two considerable rivers, and several large streams, all of which had to be bridged. These rivers became flooded after heavy rains, and in many instances swept away small bridges, culverts, &c., each heavy storm causing a further delay. It rained on 31 days out of the 61 in the months of June and July, and rain accompanied by the most violent thunder and lightning, such as is seldom seen out of the tropics. The prospect before us at one time was most gloomy, and those best acquainted with the route we had to pass over, laughed in our faces when we talked of going to Fort Garry, and *returning* by the end of September. Under these circumstances it was necessary to find some means of supplementing the road, and relieving the transport. Colonel Wolseley determined to try to send up his boats by the river Kaministiquia, which flows out of Dog Lake, and is joined by a river coming from Lake Shebandowan. This had been declared impracticable, on account of numerous falls and heavy rapids, but after consulting Mr. McIntyre, the officer in charge of the Hudson's Bay Company's post at Fort William, the experiment was tried. Captain Young, of the 60th, was the first to make the attempt with his company, and succeeded in getting up as far as the Matawan Bridge, after very severe and arduous labour. Finally, almost all the boats were taken up by this route, and a great strain taken off the transport, which was thus enabled to be devoted solely to the conveyance of provisions and stores. Every mile of the river that could be made available was utilized, the following being the mode finally adopted for getting our stores and boats from Prince Arthur's Landing to Shebandowan. The stores were taken by road 27 miles to the "Matawan River," the boats going up by water. Boats and stores were then taken up by water to "Young's Landing," 2½ miles further; from that point to "Calderon's Landing" the boats went by water, and the stores by the road; thence to the "Oskondagee River," the stores went up in the boats by the river; from that point to "Ward's Landing," everything was taken by road; and from "Ward's Landing" to "McNeill's Bay," on Lake Shebandowan, the stores and boats were tracked and poled up the river. This frequent breaking of bulk was most hurtful to all our stores. Many of the pork barrels began to leak, and those of the flour and biscuit required re-hooping. A cooper's shop was established for that purpose at the Lake, where fresh brine was also put into the pork barrels requiring it. All these arrangements necessitated great nicety of management, and entailed the most severe labour on the men. But the way in which they worked, officers and men, was beyond all praise. No troops in the world could have done better, and few so well.

Embarkation and Start from Lake Shebandowan.

The month of July was half over before the boats and stores were

brought near to the Lake; at last, however, the start was made. On the 16th July the first three brigades of boats, comprising two companies of the 60th Rifles, and the Royal Artillery and Royal Engineers, embarked at Shebandowan, under command of Colonel Feilden. Only two of the guns were embarked in the boats, the other two being left at Prince Arthur's Landing, as an armament for the stockaded redoubt which had been constructed there. Each company had six boats, and each boat contained eight soldiers, two voyageurs, and sixty days' provisions. The brigades followed each other in quick succession, the 60th Rifles leading the way, then the 1st Ontario Rifles, and lastly the 2nd Quebec Rifles. Colonel McNeill superintended the embarkation, and remained at Shebandowan until the whole of the force had embarked.

Description of the Route.

About 70 or 80 miles from Thunder Bay is the lowest pass (839 feet above Lake Superior), of the hills which form the great watershed separating the rivers that flow in a north-easterly direction into the Gulf of St. Lawrence, from those that flow north westerly into Hudson's Bay. Lake Shebandowan itself is 804 feet above Thunder Bay. This will give an idea of the labour involved in dragging the heavy boats and stores to the point of embarkation. After crossing the watershed the route of the expedition lay always down stream, through lake after lake, of varying size and beauty, and rivers and streams, some narrow as a mountain brook, others wide as an estuary. The labour at the oar was incessant from dawn to dark of the long summer's day. For a description of the scenery I must refer you to the pages of "Blackwood's Magazine," as the limits of this brief lecture will not permit me to dilate upon it. One day's work resembled another with the advantage of change of scene each day, and hour of the day. The men were roused from their hard earned repose at the first flush of dawn, and by 5 o'clock were in their boats, and under weigh, till about 8 o'clock; when an hour's halt at the nearest convenient spot, usually some pretty little island, was allowed for breakfast, another hour at 1 P.M. for dinner, and then a halt for the night about an hour before sunset, to enable the camp to be pitched, and supper cooked and eaten before dark. Such was the routine, broken only by arriving at a portage, when everything had to be taken out of the boats and carried across the portage on the men's backs. For this purpose *portage-straps* had been served out to the men.

Portage-straps and Rope-slings.

A portage-strap is a piece of stout ox-hide leather, about 10 or 11 feet long, with a broad part in the centre 4 inches wide, the ends tapering to an inch in width. These ends were tied round the barrel or package to be carried in such a manner as to leave a loop in the centre, just large enough to admit of a man's head being passed through; the barrel was then hoisted on to the back, the broad part of the strap passing across the forehead, so that the whole strain came

on the back bone and vertebræ of the neck. An Indian usually clasps his hands behind his head to help the "leverage," and in this way will carry as much as 400 or 500 lbs. Our men soon got into the way of it, and would trot off with a barrel of pork on their backs weighing 200 lbs.

Another method adopted for carrying the heavier loads was by means of a kind of hand-barrow, made of two small poles (which are easily cut anywhere in the woods), and united by a couple of slings made of 2-inch rope with a loop at each end. The poles were run through the loops, and the barrel rested on the centre of the rope-slings. The men used to walk between the poles, the ends of which they held in their hands, as sedan chairs used to be carried in England, and to ease the strain from their arms (which would otherwise have been very great) they used to fasten their portage-straps to the poles, letting the broad parts rest across their shoulders, like a milkman's wooden yoke. Colonel Wolseley had a number of these rope-slings constructed before leaving Prince Arthur's Landing and issued to each boat. They were very generally adopted, and found to answer the purpose admirably.

Manner of Crossing a Portage.

On arriving at a portage the custom was to unload the boats, and carry the stores, &c., over first. Whilst this was being done the voyageurs set to work with their axes to clear a broad road ten feet wide, and to lay down rollers or skids for the boats. For this purpose young trees of poplar and spruce were best adapted, their bark being smooth, and offering the least resistance to the keels of the boats. The speed with which this work was performed by these experienced back woodsmen was astonishing, a few hours sufficing to make a road over a portage of 800 or 900 yards in length. This labour of clearing and cutting out the portage roads fell, of course, only on the leading detachment, Colonel Feilden's three brigades, which had the honour throughout of being the pioneers of the force. As soon as the road was cut out, the boats were then hauled over by main strength, by means of a stout towing line with which each boat was provided. Over a rough, hilly portage from 20 to 30 men would be required for one boat; over a level, smooth portage half that number was generally sufficient. We had 47 of these portages to get over between Lake Shebandowan and Fort Alexander, varying in length from twenty yards to a mile and a-half. This severe labour was performed without the slightest murmur of discontent, our only fare being salt pork, hard biscuit, and tea.

The way in which all ranks worked, Officers and men alike, was beyond all praise, and required to be seen to be appreciated. It is the custom just now to disparage the British Officer, to call him lazy, idle, and ignorant of his profession, and to compare him unfavourably with the Officers of the continental armies. But if he is idle during the monotony of garrison life, the very pursuits of his hours of idleness fit him for the hard work of campaigning when the time comes. Hunting, shooting, fishing, boating, cricket, all these tend to make him

hardy and invaluable on active service. In the Red River Expedition, the Officers vied with their men in carrying heavy loads, and set them a noble example which their men were not slow to follow. If some of our would-be Army reformers could have seen, as I did, Officers staggering over a portage with a barrel of pork on their backs, or rowing in the boats for hours together and urging on their men by voice and example, they would be inclined to modify their disparaging opinions of the British Officer Much of the success of the Expedition was due to the manner in which Officers and men worked, both regulars and militia. The latter were determined not to be outdone by their brethren of the Regulars, and in this spirit of emulation and honest rivalry, each brigade tried how far they could get on each day, and how quickly they could get over a portage.

We were eighteen days reaching Fort Frances, arriving there on the 4th of August; at this time the whole of the expeditionary force, consisting of 21 brigades, was scattered over the 200 miles between Lake Shebandowan and Fort Frances. Colonel Wolseley himself sometimes accompanied the leading brigades, at other times remained behind to make various necessary arrangements or alterations.

From Fort Frances to Fort Alexander.

From Fort Frances our route lay through Rainy River, Lake of the Woods, and the River Winnipeg, to Fort Alexander. In the Rainy River district we saw the only fertile-looking land met with during the whole route. Groves of bass-wood, and sturdy oak, and open glades stretching away into a forest of elm, ash, and balsam-poplar, met the eye; while the grass was green and luxuriant, and studded with wild flowers and climbing plants. The Indians that inhabit this part of the country belong to the tribe of Chippewas. A treaty had been made with them granting us the right of way through their country. We met a few canoe-loads of them along the route, fine looking fellows, but such importunate mendicants, that we were glad to get rid of them.

Everything on the American continent is on so gigantic a scale that our small lakes and rivers sink into insignificance beside those that the Expedition passed through. Rainy Lake, for instance, is 50 miles long; Rainy River 75 miles long; Lake of the Woods 72 miles long, and nearly as many broad; and Lake Winnipeg is 264 miles long, with an average width of 35 miles, and covers an area of 9,000 square miles. The River Winnipeg, which we had to descend, is full of tumultuous cascades and foaming rapids, and the scenery is of the wildest and most picturesque description, but the navigation is full of danger, and requires the most skilful management. The boats of the Expedition were most fortunate in descending these dangerous rapids without any loss of life. Some few trifling accidents occurred, but no lives were lost. Much of this was due to the fact that the loyal people at Red River had raised and equipped a fleet of six large Hudson Bay boats, manned with skilled voyageurs well acquainted with the rapids of

the Winnipeg River; these boats were sent up to Rat Portage to meet the Expedition and help them down the river.

Concentration of the Regular Troops at Fort Alexander.

Fort Alexander, at the mouth of the Winnipeg, was the rendezvous of the Force; the Regulars were concentrated there by the 20th of August, having been just thirty-five days getting there from Lake Shebandowan. As the latest information received from Fort Garry led to the belief that the Regulars would suffice to overcome any opposition, and as time was of the utmost importance, Colonel Wolseley determined to push on without waiting for the Militia, who were ordered to follow as fast as possible.

On the 21st August the little fleet of 50 boats (8 brigades) set sail from Fort Alexander, and, having a favouring breeze across Lake Winnipeg, entered the mouth of the Red River at noon on the 22nd, and reached the Stone Fort, twenty miles below Fort Garry, at 8 a.m. on the 23rd. Here the boats were lightened of all superfluous stores, only four days' rations being taken on, so as to reach Fort Garry, if possible, before dark. A company of the 60th was detached on our right flank (the left bank of the river) as an advanced guard and flanking party. This company was mounted on ponies and country carts, and had two signalmen with flags to enable them to communicate with the boats. Their main body marched up "The King's Road" (which occasionally is as much as a mile distant from the river, and at other places quite close), with an advanced party, 500 yards ahead, and connecting files to the river's bank. This party had orders to stop all persons going *to* the Fort, but not to interfere with people coming *from* the Fort. An Officer was sent along the right bank of the river on horseback to keep a little ahead of the boats and communicate with the main body every now and then. By means of these precautions it was found that our approach was unknown until the boats were actually in sight, and the settlers turned out to see the troops and welcomed their arrival by firing off guns, and other demonstrations of joy. The little fleet continued its advance up the river in two lines, preceded by Colonel Wolseley in his gig. We had hoped to have reached Fort Garry that night, but were unable to do so, and camped on the left bank of the river about six miles below the fort. Colonel Wolseley sent spies into the village during the night to collect information, and they brought back word that nothing but vague rumours of our approach were known in the Fort, and that these were discredited by Riel, who had lately summoned a meeting of the French half-breeds, and endeavoured to persuade them to support him in resisting the entry of the troops: that Riel still held possession of the fort, and would certainly fight if he could get his men to back him up. That night outlying piquets were thrown out on both sides of the river under the command of Officers, and a chain of sentries posted so as to cut off all communication between Fort Garry and the lower settlements, and to prevent the news of our approach from being conveyed to the fort.

Advance on Fort Garry.

It had been Colonel Wolseley's intention to have marched at a very early hour next morning on the fort, but a terrific gale of wind from the north-west, accompanied by torrents of rain, came on about 10 P.M., which rendered the roads ankle-deep in black, gluey mud and almost impassable; he was therefore obliged to abandon this plan and to continue the advance in the boats. As the men were thoroughly wet, they breakfasted before embarking, and rowed on up the river in the same order as the day before, till they reached Point Douglas, two miles from the fort, where they were ordered to disembark on the left bank. The men fell in in open column of companies and marched off in column of fours, with a company in skirmishing order 500 yards in advance and another company as a rear guard. The guns were limbered up behind a couple of country carts provided for the occasion. In this formation we advanced on Fort Garry, and passing round the village of Winnipeg, which we kept on our left flank, marched over the prairie on to the north gate of the fort, the rain still falling in torrents. In the village people said that Riel would certainly fight, and as the gates were closed and no flag was to be seen, we began to think that after all our labours would not be in vain; we could see a gun mounted over the gateway and commanding the prairie over which we were advancing, and we momentarily expected it to open fire. But as we got nearer we could see that there were no men standing to the gun, and Colonel Wolseley sending some of his staff round to the south gate, they galloped back reporting that it was open and the fort deserted. The troops accordingly marched in by the south gate, the one facing the Assiniboine River, and then discovered that Riel and his friends, unable to get their men to stand by them, had waited until the very last moment and then had ridden off, taking the direction of the United States. The union jack was then hoisted on the flagstaff, a royal salute fired and three cheers given for the Queen, and thus was Her Majesty's authority restored in the Red River country after a bloodless victory.

Return of the Regulars.

The troops were housed inside the fort until the rain had subsided, as they were drenched to the skin. Riel and his adherents made good their escape into the United States, no attempt being made to pursue and capture them. The companies of the Militia began to arrive after a few days, and the Regulars re-embarked on the 29th of August and following days to retrace their weary journey up the Winnipeg River and across the lakes and rivers that lay between them and civilization. Only one company of the 60th was sent across the road to the north-west angle of Lake of the Woods, and succeeded, after very hard work, in getting through the swamps, their baggage and provisions being carried on pack-horses. The two battalions of Militia were quartered, one at Fort Garry the other at the Stone Fort, and by the 1st of September, after only one week's rest, the whole of the Regulars had

left on their return journey. Colonel Wolseley himself remained till after the arrival of the Lieutenant-Governor, Mr. Archibald, when he handed over the command to the senior officer of the Militia and returned by the same route to Canada, there to be received with open arms by all classes of the citizens.

At Montreal he was presented with a congratulatory address, and entertained at a public dinner, before his departure for England. The regular troops, under the command of Colonel Feilden, got back to Prince Arthur's Landing about the first week in October, and reached Toronto after an absence of nearly five months.

In concluding this brief lecture it may perhaps not be amiss if I were to compare this expedition in its political bearings and results with other expeditions of late years, and notably with the recent Abyssinian Expedition. The latter was undertaken for the purpose of rescuing a few English subjects from the hands of a barbarian chieftain, it was supported by the sentiment of the whole English nation, it was magnificently and successfully carried out under the direction of Sir Robert Napier, and, happening at a time when no foreign war distracted the attention of England, it commanded the sympathy and, by its success, flattered the vanity of all classes of Englishmen, but at the cost of £15.000,000! The Red River Expedition, while it had a greater distance to traverse, and greater physical obstacles to surmount, was over-shadowed in its very infancy by the great European war, which entirely absorbed all the interest and sympathy of the public. It is not, however, too much to say that in its political bearings and results no event of similar importance has for many years been accomplished with so little expenditure of time and money. From first to last the time occupied was five months, the expenditure about £400,000, of which England only pays one-fourth. Under the energetic and skilful conduct of Colonel Wolseley no accident or mistake occurred, and throughout the whole expedition not a single life was lost. When the din of strife on the Continent of Europe shall have subsided, then, perhaps, may the less dazzling accomplishment of the Red River Expedition claim its share of public attention as an event which carried and asserted the power of Great Britain to the far West, and while opening up a virgin soil for her sons in a distant land, has added yet another province to that Empire on which the sun never sets.

Departure.							Numbers.						
	Date.	Hour.	Brigade.	Number of boats.	Officer Commanding.	Regiment Embarked.	Officers.	N. C. O. and Men.	Voyageurs.	Guides.	Total.	Biscuits.	Flour.
												brls.	brls.
1.	July 16th ..	8.30 P.M.	A	6	Capt. Young	1st Bn. 60th.. ..	5	50	12	1	68	34	20
2.	„ „ ..	„	B	6	„ Ward	„	4	50	12	..	66	28	31
3.	„ „ ..	„	C	5	Lieut. Alleyne, R.A. ..	R. A. and R. E. ..	2	38	10	..	50	21	17
4.	„ 17th ..	3 P.M. ..	D	7	Capt. Dundas	1st Bn. 60th.. ..	4	50	14	1	69	37	31
5.	„ „ ..	4 „ ..	E	6	„ Buller	„	3	50	12	..	65	50	32
6.	„ 18th ..	6 „ ..	F	6	„ Northey	„	3	49	12	1	65	50¾	37
7.	„ 19th ..	4.30 P.M.	G	7	„ Wallace	1st Bn. 60th A.S.C. and A.H.C.	5	58	14	1	78	40	42
8.	„ 21st ..	8 A.M. ..	H	6	„ Calderon.. ..	1st Bn. 60th.. ..	4	49	12	1	66	51	33
9.	„ „ ..	4 P.M. ..	I	6	„ Scott	1st Ontario Rifles ..	6	48	12	1	67	54	35
10.	„ „ ..	6 „ ..	Gig	1	„ Huyshe, 1st R. B.	H. Q. Staff	2	4	2	..	8	2	2
11.	„ 22nd ..	12·30 P.M.	K	6	„ McDonald ..	1st Ontario Rifles ..	4	49	12	..	65	*49	37
12.	„ „ ..	3.30 „	L	6	„ Herchmer ..	„ „	3	48	12	1	64	†60	37
							45	543	136	7	731	476¾	354

APPENDIX A.

EMBARKATION RETURN, Red River Expeditionary Force, from McNeill Bay, Lake Shebandowan.

Biscuits.	Flour.	Pork.	Sugar.	Tea.	Beans.	Preserved potatoes.	Pepper.	Days' rations, for total.	Ammunition, rounds.	Augurs.	Axes. Felling.	Axes. Pick.	Blankets.	Fuze.	Gimlets.	Hammers, sledge.	Hammers, small.	Hatchets, hand.	Kettles, Flanders.	Ovens, Field.	Pans, Frying.	Bedding, Hp., bags of.	Powder kegs.	Rope lashings.	Rope, Manilla coil.	Saws + cut.	Saws, hand.	Scales and weights.	Shovels.	Spades.
brls.	brls.	brls.	brls.	chs.	bgs.	case	lb.							case										coils						
34	20	45	6	6	8	6	8½	*Vide* last column.	5,000	..	10	5	..	..	..	..	..	11	10	..	7	..	..	..	..	..	..	..	5	5
28	31	42	6	6	10	8	8		6,000	..	10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5
21	17	25	4th	3rd	4	8	5		..	2	12	16	..	1	2	..	1	10	8	..	6	..	2	1	1	..	..	..	8	4
37	31	52	8	7	14	8	9		6,000	..	12	6	..	..	..	..	..	12	12	..	8	..	..	..	..	..	4	..	6	6
50	32	42	6	5	9	8	8		5,000	..	10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5
50¾	37	44	6	6	13	8	8		5,000	1	10	5	25	..	2	3	2	10	15	..	7	..	..	..	..	2	3	..	5	5
40	42	50	7	7	13	8	9		6,000	..	19	11	..	..	..	..	..	22	13	1	18	..	..	..	..	..	..	1	13	13
51	33	44	6	6	11	8	8		5,000	..	10	5	..	..	..	..	..	10	10	..	7	8	..	..	..	5	1	..	5	5
54	35	46	7	6	10	9	8		5,000	..	10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5
2	2	3	36	18	..	1	½		..	..	2	1	..	..	..	..	..	2	1	..	1	..	..	..	..	..	..	..	..	1
*49	37	45	6	6	10	11	8		5,000	..	10	5	..	..	..	..	..	10	8	..	7	..	..	..	..	..	..	..	5	5
†60	37	44	8	6	9	9	8		5,000	..	10	5	..	..	..	..	..	10	6	..	7	..	..	..	..	..	..	..	5	5
476¾	354	432	70 47H	64 28H	111	92	88	..	53,000	3	125	74	25	1	4	3	3	127	113	1	89	8	2	1	1	7	8	1	67	64

* 47 at 48 lbs.
2 at 60 „

† 53 at 84 lbs.
1 at 60 „
6 at 42 „

APPENDIX A.

d River Expeditionary Force, from McNeill Bay, Lake Shebandowan.

Axes.																									Slings, rope.	
Felling.	Pick.	Blankets.	Fuze.	Gimlets.	Hammers, sledge.	Hammers, small.	Hatchets, hand.	Kettles, Flanders.	Ovens, Field.	Pans, Frying.	Bedding, Hp., bags of.	Powder kegs.	Rope lashings.	Rope, Manilla coil.	Saws + cut.	Saws, hand.	Scales and weights.	Shovels.	Spades.	Spikes and nails.	Tape, measuring.	Tarpaulins.	Tents, bell.	Marquees.	Large.	Small.
			case										coils							lb.						
10	5	..	..	..	..	..	11	10	..	7	..	..	..	..	..	..	..	5	5	..	..	..	6	..	15	20
10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5	..	..	..	7	..	15	20
12	16	..	1	2	..	1	10	8	..	6	..	2	1	1	..	..	..	8	4	50	1	..	6	..	12	16
12	6	..	..	..	..	..	12	12	..	8	..	..	..	..	..	4	..	6	6	..	..	..	8	..	18	24
10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5	..	..	..	6	..	15	20
10	5	25	..	2	3	2	10	15	..	7	..	..	..	..	2	3	..	5	5	..	..	..	15	..	15	20
19	11	..	..	..	..	..	22	13	1	18	..	..	..	..	..	..	1	13	13	..	..	..	11	..	18	24
10	5	..	..	..	..	..	10	10	..	7	8	..	..	..	5	1	..	5	5	..	..	..	6	..	15	20
10	5	..	..	..	..	..	10	10	..	7	..	..	..	..	..	..	..	5	5	..	..	..	6	..	15	20
2	1	..	..	..	..	..	2	1	..	1	..	..	..	..	..	..	..	..	1	..	..	..	2	..	..	..
10	5	..	..	..	..	..	10	8	..	7	..	..	..	..	..	..	..	5	5	..	..	..	5	..	15	20
10	5	..	..	..	..	..	10	6	..	7	..	..	..	..	..	..	..	5	5	..	..	..	6	..	15	20
25	74	25	1	4	3	3	127	113	1	89	8	2	1	1	7	8	1	67	64	50	1	..	84	..	168	234

* 47 at 48 lbs.
2 at 60 ,,

† 53 at 84 lbs.
1 at 60 ,,
6 at 42 ,,

Camp, *Lake Shebandowan*, 23rd *July*, 1870.

Slings, rope.		Straps, portage.	Bags, spare.	Tins of mosquito oil.	Bags, waterprf.		Medical comforts and equipment, boxes.	Tins	Canteens, Hp., A and B.	Linseed meal, boxes.	Salt, kegs.	Stones, grind.	Tobacco, boxes.	Soap, cases of.	Number of days' rations for total 731 men.
Large.	Small.				For blankets.	For accoutrements.									
15	20	36	50	6	10	5	..	30	..	..	..	..	..	..	Biscuit 54 } 85
15	20	30	50	6	10	5	..	33	..	..	..	..	..	..	Flour.. 31 }
12	16	24	30	5	8	5	..	15	..	..	..	1	..	..	Pork 66
18	24	36	81	7	12	6	..	34	..	..	..	..	..	..	Sugar.. .. 71
15	20	30	90	6	10	5	..	27	..	..	..	..	..	..	Tea 69
15	20	30	73	6	10	5	..	28	..	..	..	..	..	..	Beans 43 } 71
18	24	36	70	7	12	6	13	32	2	1	1	..	4	..	Potatoes 28 }
15	20	30	62	6	10	5	18	31	..	1	..	..	..	..	Pepper .. 69
15	20	30	60	6	10	5	7	26	..	..	..	..	4	..	
..	..	6	4	1	..	..	..	4	..	..	..	..	..	..	
15	20	33	60	6	10	5	3	27	..	..	..	..	..	..	
15	20	30	60	6	10	5	..	26	..	..	..	..	1	1	
168	234	348	660	68	112	57	41	313	2	2	1	1	9	1	

(Signed) A. Meyer,
Deputy-Assistant Commissary-General.

APPENDIX B.

DAILY RATION OF FOOD FOR RED RIVER EXPEDITIONARY FORCE.

1 lb. of salt pork or $1\frac{1}{3}$ lb. of fresh meat.
1 lb. of biscuit, or $1\frac{1}{2}$ lbs. of fresh bread.
$\frac{1}{3}$ pint of beans, or $\frac{1}{4}$ lb. of preserved potatoes.
1 oz. of tea, 2 oz. sugar.
$\frac{1}{2}$ oz. salt when fresh meat is issued.
$\frac{1}{36}$ oz. pepper.

CLOTHING ADOPTED FOR THE RED RIVER EXPEDITIONARY FORCE.

Worn on the Person.

1 flannel shirt.
1 pair woollen socks.
1 pair buff mocassins.
1 forage cap, with peak and cover.
1 serge frock (with pockets).
1 pair serge trousers.
1 haversack.
1 clasp knife.
1 tin cup.
1 waist belt.
1 mess tin } on pack.
1 great coat } on pack.

In the Pack.

1 flannel shirt.
2 pairs woollen socks.
1 pair ammunition boots.
1 thick woollen night-cap.
1 tunic.
1 pair cloth trousers.
1 towel.
1 piece of soap.
1 brush (clothes or boot).
1 comb, 1 linen bandage.
1 small book, 1 housewife.
Knife, fork, and spoon.

Evening Meeting.

Monday, January 30th, 1871.

VICE-ADMIRAL SIR FREDERICK W. E. NICOLSON, Bart., C.B., Vice-President, in the Chair.

NAMES of MEMBERS who joined the Institution between the 17th and 31st January.

LIFE.

Blake, W. H., Captain R.N.

ANNUAL.

Kerr, Herbert, Capt. 17th Regt.
Gamble, J. H., Lieut. 17th Regt.
Parkinson, F. F., Lieut. 17th Regt.
Nares, H. J., Lieut. 17th Regt.
Stephen, John S., Ensign 17th Regt.
Denny, C. C., Ensign 17th Regt.
Slaney, W. K., Capt. Gren. Gds.
Maxwell, W. H., Commr. R.N.
Penny, Stapleton, Capt. R.A.
Tennant, W. D., Sub.-Lieut. R.N.
Dwyer, L. F. W., Capt. h.-p. 17th Regt.
Elsdale, H., Lieut. R.E.
Haines, B. G., Lieut. 18th Royal Irish
Vaughan, J. L., Major-General H.M.'s Indian Army
Butler, Vere A., Lieut. R.M.L. Infy.
Maxwell, R. J., Capt. 80th Regt.
Douglas, E. O., Capt. Royal Perth Rifles
Huyshe, G., Capt. Rifle Brigade
Wainwright, J. F. B., Rear-Admiral
Shirley, J. C., Captain 100th Regt.
Marx, John L., Midshipman, R.N.
Newdigate, H. R. L., Lieut.-Col. Rifle Brigade

OFFENSIVE TORPEDO WARFARE.

By Commander W. DAWSON, R.N.

THE employment of torpedoes as a naval arm for offensive warfare, though first brought into action against ourselves during the War of Independence in the United States of America, and made the subject of elaborate experiment by Mr. Fulton, at the beginning of this century, did not attract much attention until the recent civil war in North America. During that fratricidal conflict, twenty-five Federal vessels are known to have been sunk or destroyed, and nine others more or less injured by torpedoes, which, the Secretary of the United States' Navy, in his Report for 1865, remarks, "have been more "destructive to our naval vessels than all other means combined." The Confederate Navy had also one ship destroyed by Federal torpedoes, and three, accidentally, by their own weapons. Of the Federal vessels thus destroyed or injured, twenty-nine suffered from torpedoes defensively employed in harbours, rivers, or roadsteads, and five from the offensive attacks of boats or steam-vessels armed with torpedoes projected at the extremities of poles or outriggers. The only Confederate armour-clad ship thus destroyed by the Federals was sunk by a similar offensive application of the torpedo. It is to this latter mode of warfare that I wish to direct attention.

In limiting my paper to the consideration of "naval torpedo tactics," I am influenced by the silence which my recent employment, during five years, as Secretary to the Committee on Floating Obstructions

necessarily imposes, as to the results of its experimental researches, which had reference principally to the various modes by which the ignition of torpedoes might be effected, and to the laws which govern the effects of their explosion.

After those five years' education at the public expense, and chiefly in consequence of it, the Admiralty have, in their inscrutable wisdom, deemed me unfit to serve Her Majesty as a Naval Officer, so that whatever public benefits their Lordships may have anticipated from my appointment to the study of this new arm, are necessarily thrown away. Before, however, forgetting that the best energies of my mind and body during twenty-five years had been devoted to the sea service, and before retiring from naval view, I am anxious to place on professional record some of the thoughts which the country paid me to acquire. In doing so, I am bound not to divulge confidential information, which, moreover, is to be found in the Reports of the Floating Obstruction Committee; and I propose, therefore, to confine my observations to such facts as have been already made public. This explanation will, I trust, excuse my silence on many interesting details into which I might otherwise be expected to enter.

Most naval and military inventions suffer at the outset from the overweaning zeal of their advocates, who commonly over-rate the consequences of the introduction of the new invention, and disparage in unmeasured terms, the instruments previously in use. The torpedo is a weapon unquestionably much over-rated by its advocates, but much undervalued by those who have not studied its probable, not to say possible, development. As part of a system of harbour defence, it is absolutely essential; but alone and undefended it would be futile. As an auxiliary weapon of naval war, it will add immensely to the power of offence; but alone, unprotected by guns, by armour or by darkness, little can be expected from it. Earl St. Vincent truly described this as "a mode of war which they who commanded the seas did not want, "and which, if successful, would deprive them of it." Its claim upon our attention now is, that in a maritime war, it will add immensely to the offensive powers of that nation which first brings it into a naval action; whilst that seamanship and nerve, which have ever been characteristic of the British Navy will, if properly instructed, secure to us peculiar advantages in employing the torpedo against others.

A torpedo is simply a charge of gunpowder, gun-cotton, or other explosive agent, enclosed in a water-tight envelope either of glass, india-rubber, wood or metal. If gunpowder be employed, the stronger, within limits, the metal case in which it is enclosed,—and, if the charge be very large, the more numerous the points of ignition,—the more likely that the whole amount will be consumed. When gun-cotton, ignited by detonating fuzes, is the explosive agent, great strength of case, with its additional weight, may be dispensed with.

The confinement of gunpowder in water-tight cases and its submarine explosion, for the destruction of floating and other bodies, is almost as old as "villainous saltpetre" itself. Great difficulties had, however, been experienced in devising means by which the explosion could be brought about at the desired moment. Many projects have

been proposed from time to time, and various methods been adopted, on service, at different periods. Nothing is, however, to be learnt from these up to 1854–56, when the Russians employed against us torpedoes, in which ignition was effected by the collision of a passing ship, either by the liberation of a well-known igniting acid, or by an ingenious self-acting electric contact-maker. Being planted in undefended positions, many of these torpedoes were easily removed by the boats of the fleet, and the weapon was consequently held in little estimation. The amount of gunpowder used by the Russians was only 8 lbs. to 12 lbs. These insignificant charges caused no serious damage to the two ships which struck against them, owing, as was supposed, to the few inches of intervening water; hence a false impression arose that submerged explosions were ineffective unless in absolute contact with the object to be destroyed.

The igniting arrangements of the Confederate Americans consisted, in some cases, of common friction gun-tubes embedded in the charge, and attached to long trigger-lines, to be pulled by an operator concealed on shore, or by the interception of a passing ship. In a more advanced stage of their experience, several metal fuses, each enclosing a small glass vessel embedded in chlorate of potash and filled with sulphuric acid, were inserted in the torpedo case in such a manner that the collision of a passing ship might break one or more of the glass vessels, thus combining the acid with the chlorate, and producing ignition. These again were superseded by fuzes charged with a sensitive fulminate, which ignited with a very gentle blow or, even, with a predetermined pressure. Various other means of effecting ignition by chemical means were employed, but they all had the inconvenient character of being equally dangerous to friend and foe, and could, therefore, only be applied in waters which were not likely to be used by their own ships.

The only igniting arrangements extant, whereby absolute safety to the operators and their friends can be secured, are those in which electricity is employed. Some such were used in several positions, and were brought into destructive operation in the case of at least one Federal ship. They were, however, of the clumsiest kind, the resources of the Confederacy being at that time very limited, and their electrical information equally so. Later in the war, more suitable electrical fuzes and apparatus were procured from this country, but though placed in position, no opportunity was afforded for their destructive action.

The present igniting apparatus may be classed under two heads, each of which has special advantages:—

1st. Various chemical fuzes, always self-acting, which lose in safety and certainty what they gain in simplicity of employment.

2nd. Electrical arrangements, self-acting or ignitable at will, as desired at the moment. These are more or less complicated, and lose in simplicity what they gain in safety and certainty.

Until quite recently, the destructive area of given charges of gunpowder exploded at given depths, was little understood. That it was extremely limited, all believed; but what effect, depth of immersion

had in increasing the area of destruction was imperfectly apprehended. In a recent article in the "Times," the absurdities published by Lieutenant-Colonel von Scheliha, in his work on Coast Defence, are accepted as truths. Von Scheliha gravely states, as a fact ascertained by experiment, that 1,000 lbs. of gunpowder, submerged 18 feet, and in a position only 4 feet distant from a ship, produced hardly any effect whatever! The effect of vertical distance upon the results of an explosion beneath a vessel is small; and the depth at which it would cease to act destructively upon a ship immediately over it has yet to be ascertained. In determining the minimum effective charges for offensive war, it is, then, the horizontal range that we have chiefly to consider, and the depth of immersion which will produce the best results. Von Scheliha truly observes that 50 or 80 lbs. of powder produce the greatest effect when immersed 12 feet, and that "torpedoes containing 150 lbs. of powder should be sunk to a depth of 15 feet. Torpedoes attached to the spars of torpedo boats should be lowered to depths corresponding to these data."

Confederate Engineer Officers officially reported that "100 lbs. of powder 15 feet from the bottom of a vessel would break her sides and bottom." This opinion could hardly have referred to a lateral distance of 15 feet, even when immersed to that depth which is found to produce the greatest range. A boat would probably be safe from the explosion of 100 lbs. of powder, duly submerged, at that horizontal range, though a line-of-battle ship might be destroyed at 10 feet lateral distance.

Not to refer to unpublished experiments, made in this country, it appears from Commander Fisher's "Treatise on Electricity," that a 100 lbs. charge of gunpowder was exploded with 10 feet immersion, at a horizontal distance of 17½ feet from a launch and of 4 feet from a waterlogged frigate, without any injury being sustained by the boat; and that a similar explosion, with the same immersion, was effected at a lateral distance of 22½ feet from the stem of a steam-launch, having the steam up, without any injurious shock to the engines, boilers, or boat.

The principal destructive area of such a charge has probably a radius of about 9 feet; but it may be that a thin-skinned boat would sustain injury at a further distance of a foot or two: whilst the radius of surface disturbance might be more than double that of the real destructive range. Perfect immunity to the operating vessel, engines, and crew would be amply secured, provided that the explosion of 100 lbs. of gunpowder, or 40 lbs. of gun-cotton, took place at a lateral distance of 20 feet, whilst the greatest destructive range would be obtained with 10 or 12 feet immersion.

Our own sloop of war, "Terpsichore," of 603 tons, was instantly destroyed at Chatham by 150 lbs. of powder placed 22 feet beneath the surface and 19 feet in an oblique line from the nearest part of the bilge; but the charge was only two feet laterally from the plane of the ship's side, though 12 feet lower than her keel. This experiment does not, therefore, throw much light on the lateral range of such a charge.

The principal destructive horizontal range of 150 lbs. of powder when submerged 15 feet, that is to say, the distance at which the

bottom of a wooden line-of-battle ship would be so penetrated as to cause instant sinking, is probably about 11 feet. A few feet beyond this range, a thin-sided vessel would sustain injury, but the destructive area is so sharply defined that the smallest boat might be quite safe from the direct effects of the explosion at double this distance.

We have long known, from the "Excellent" experiments in 1853, that 25 lbs. of powder placed in contact six inches below the water-line of an old line-of-battle ship, made an open hole of 35 square feet; and if actual contact could be made absolutely certain, a charge of this kind might be adopted; but American experience warns us against the attempt to repeat in actual war the nice calculations of peaceful experiments—a truism which the last paragraph in the "Manual of Gunnery for Her Majesty's Fleet" ignores, when it suggests the employment of about one-half of the charge which repeatedly failed in war, or about one-quarter of the minimum amount with which, considering the interests at stake, any sane Officer would attempt hostile operations.

We do not yet know what increase of charge, if any, cellular iron-bottomed ships may necessitate. The experiments, proposed three years ago, to ascertain this point are about to be made, and it would be unsafe to foretell the result; but for our present purposes we may assume that any additional safety afforded is of little practical value, and will not lead to any considerable increase of the proposed charges.

Compressed gun-cotton has unquestionable advantages over gunpowder for charging naval torpedoes. Not only does one-fourth of the weight and bulk in gun-cotton produce equal results at close lateral range, but maximum effects are obtained by detonating fuses in the slightest water-tight envelopes, whereas thick and heavy iron shells are essential to maximum results from gunpowder. There would thus be a difference of 2 or 3 cwt. between an effective torpedo charged with 150 lbs. of gunpowder, and one charged with its equivalent, 38 lbs. of gun-cotton. Though equal vertical ranges are thus obtained, it appears from careful, prolonged, and elaborate experiments instituted by the Royal Engineers, and referred to by Colonel Fisher, C.B., R.E., in his paper on "Gun-cotton Applied to Demolitions,"* that, "as regards "the lateral or horizontal destructive effect, equal radii would be "obtained with a charge of gun-cotton of two-fifths the gunpowder "charge; the actual damage done within that radius being, however, "greater in the case of the gun-cotton than in that of the gunpowder."

Thus, whilst 38 lbs. of compressed gun-cotton would produce results equal to 150 lbs. of gunpowder at short lateral range, 60 lbs. would be required to destroy a ship at the horizontal distance of 11 feet.

The essential principles of a good torpedo are—

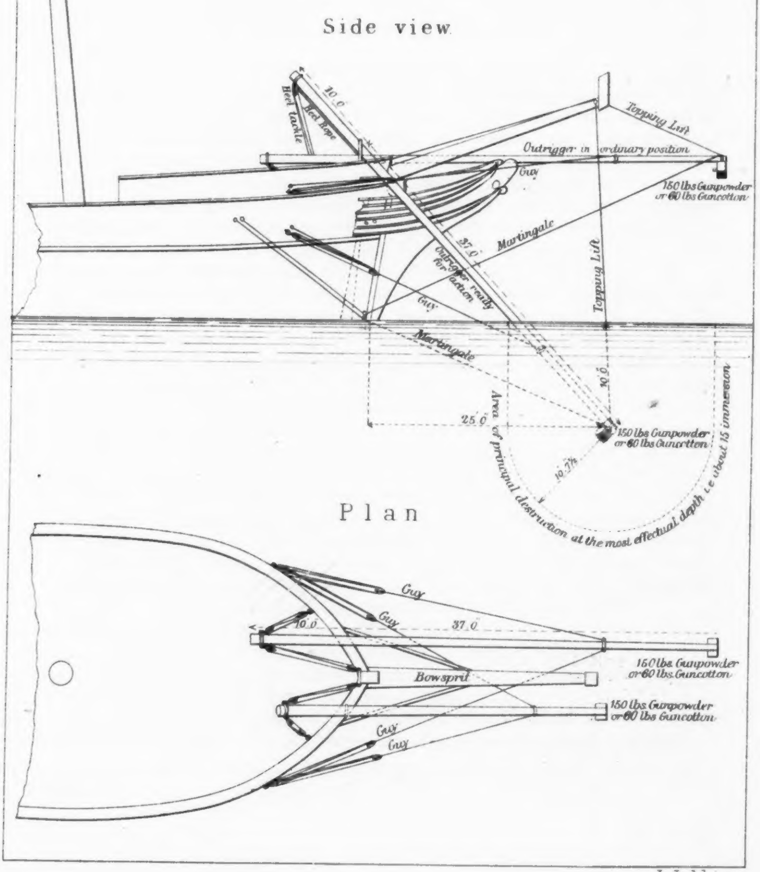
1. Perfect safety to the operators, and to friendly ships.
2. Perfect certainty of action under all reasonable conditions.
3. Simplicity of application and management.

Of the variety of proposed applications of the torpedo to offensive warfare, three only appear deserving of serious attention, viz.:—

* See Journal of the Royal United Service Institution, vol. xiv, No. LX, 1870, page 447.

DOUBLE OUTRIGGER TORPEDOES for a SLOOP OF WAR.

Spar for projection from any part of the Ship



J. Jobbins

I. Outrigger torpedo ships or boats, such as have been used in the American Civil War.

II. Towing torpedoes, such as are proposed by Commander F. Harvey, R.N.

III. Self-contained locomotive torpedoes, such as are suggested by Messrs. Lupin and Whitehead, from Austria.

I. The object to be attained by an outrigger-torpedo ship is to project at the extremity of a spar, an effective explosive charge, suitably immersed, to a safe distance from the operating vessel, and then to explode the torpedo when it is within destructive range of the hostile ship. To meet these requirements, a torpedo, containing 100 lbs. to 150 lbs. of gunpowder, or, what is preferable, 40 to 60 lbs. of gun-cotton, should be immersed at least 10 feet, and be projected to a horizontal distance of at least 20 feet from the operating vessel. Though the immersed extremity of the projecting pole would be broken off by the concussion, the shock sustained by the rest of the apparatus and the longitudinal thrust are very trifling. The outrigger and charge should be capable of being rapidly replaced by other outriggers and charges, so as to be able to repeat the explosion quickly, and should be provided with efficient safeguards to prevent the possibility of the explosion being effected, owing to confusion, darkness, or ignorance, at less than the specified distance from the operating vessel. When open boats are employed, sloped awnings should be fitted over the fore part, to throw off any falling water, which might otherwise, if the above rules be infringed, swamp a small boat.

Plate VII. Double Outrigger Torpedoes for a Sloop of War.

This is a drawing of the bow of a sloop-of-war of the "Amazon" class, (the vessel that ran into the "Osprey,") and was lost; it will show the main principles. I want merely to illustrate principles, not to advocate a sealed pattern, which must first be experimentally discovered before it is sealed. It displays two outriggers supported by crutches under the head, and provided with heel ropes, heel tackles, topping lifts, guys, and martingales. The charge is 150 lbs. of gunpowder, or 60 lbs. of gun-cotton, and is projected to a horizontal distance of 25 feet from the vessel, and to a depth of 10 feet.

The curved line in chain dots, 10½ feet from the charge, represents the distance within which complete destructive action, to a large ship of war, may be supposed to extend. The destructive action to a thin boat might extend to a foot or two outside that line. The water would be disturbed right up to the cutwater of the operating vessel; but no injurious effect from the direct action of the charge could result to the operators. There would be a very slight thrust in the direction of the pole sufficient to break a rope yarn. So that there is no danger to be anticipated from the direct action of the explosion. Everybody knows that when a vessel with bowsprit and head gear runs against another vessel at sea, the outside gingerbread work must go; but in other

respects no harm can result to the operating ship by the direct action of the explosion.

Only one outrigger should be placed in position for action at a time, if they are projected within disturbing range (say 15 feet) of each other. The outriggers may be used from any part of the ship, as circumstances require.

There should be special safeguards provided to prevent the possibility of outriggers being projected to an insufficient *lateral* distance.

There is nothing in the nature of such an apparatus to prevent its employment by vessels of all sizes and descriptions, the large ironclad, the ordinary gunboat, mercantile steam ships, steam tugs, and open boats of all sizes capable of carrying a sufficiently long spar. Neither is there anything peculiar to such an appliance calling for a specially constructed vessel to carry it. Albeit, if only a portion of the fleet were to be so armed, a natural preference would be extended to those of the smaller vessels which had the greatest speed and best turning powers.

It is not very creditable to the Navy that, though nearly six years have elapsed since the American Civil War, and the Royal Engineers have, in the interim, added immensely to our stock of exact information on every part of this subject coming within their sphere, we are quite ignorant of the commonest details of that portion dependent upon the experimental researches of nautical men, and have to speculate on probabilities where experimental data ought to be abundantly forthcoming. It is true that both the "Excellent" and "Cambridge" have classes for teaching electricity, which they appear to confound with torpedo instruction. As well imagine that the manufacturers of quill tubes were trained gunners. But I cannot find out that a single naval torpedo, with its appliances, such as would be used in actual warfare, exists; or that a single serviceable charge has ever been exploded, with the officers and crew in the boat under conditions similar to actual service. Nor has any intelligent attempt been made to gain experimental experience as to the best means of manipulating outriggers from steam-vessels; as to the speeds and weather the outrigger can be used in; how fresh outriggers and charges can be most efficiently and rapidly substituted, with due regard to a safe extent of projection and immersion; from what portions of the vessels they can be used under varying conditions of battle; or the thousand and one questions which actual experience and many minds will alone raise and solve.

This much we know, that lower-booms often, accidentally, swing forward under the bows, into the position of torpedo outriggers, when ships are going at various speeds up to ten knots, and that the booms are never, and the topping-lifts rarely, injured; yet, in these instances, the topping-lifts are always at bad angles for supporting the booms, and are not aided by the proposed props or crutches beneath the spars.

All that is taught beyond the mere electrical tuition is contained in a few dogmatic paragraphs in the "Manual of Gunnery for Her Majesty's Fleet," which are based on the utterly unpractical assumption, which all American experience forewarns us against, that a small

charge is to be brought into actual contact with the hostile ship. It is true that a few tentative explosive experiments were made by the "Excellent," at the suggestion of others, and are embodied in "A short Treatise on Electricity," by Commander Fisher, R.N., which is an excellent class book on that subject. Those tentative explosive experiments with the iron powder cases, also suggested by others, have, most unfortunately, been mistaken for actual torpedoes and sealed patterns; and further research has, it is said, been stayed, just where it should have begun. However that may be, I am unable to learn that any steps have been taken to familiarize the seamen of the fleet with the manipulation of naval torpedo apparatus, or to place Officers in a position to gain experience in manœuvring ships and boats, with a view to the explosive destruction of hostile vessels. It is true that we occasionally hear of pretty displays of marine water-works at Portsmouth and Devonport, miscalled torpedo experiments. As these are, however, meant for amusement and not for experimental research, they do not afford that information which might result from systematic experiments intelligently conducted, with a set purpose of resolving practical problems, or of determining those questions which must necessarily arise in actual war. They are utterly unworthy of the head-quarters of scientific naval gunnery, and would be undeserving serious attention, were it not that these gunpowder fountains are commonly mistaken for torpedo experiments.

In default of all useful experimental data from our own Navy, I am obliged to have recourse to the crude attempts made by the Americans to gain experience in actual war, of which imperfect but tolerably reliable information is to be found in the Annual Reports of the Secretary of the United States Navy for 1862–5; or, in a more complete form, in an excellent work on "Submarine Warfare, Offensive and Defensive," by Lieut.-Commander J. S. Barnes, U.S.N. Though Commander Barnes's mere electrical information is, naturally, far below our own; and though I am not prepared to endorse all his opinions as to torpedoes; his eminently practical work is one which deserves a place in every naval Officer's library.

The Confederates affixed the outrigger apparatus to at least one ironclad ship, and to many steam vessels of all sizes, in addition to their regular armaments; but so faulty and unsafe were the contrivances, and especially those affecting the ignition, that the operators had little confidence in their own weapons; which they were, moreover, often called upon to use without any previous experience of their action. Hence only five offensive attacks are known to have been made on Federal ships, of which only one resulted in the complete destruction of the hostile vessel. The failures will be found, however, even more instructive than the one Confederate success.

Almost all the elements of failure will be found concentrated in the vessel employed for the first offensive torpedo operation. It was at 10 p.m., on the 5th October, 1863, that the Confederate steam vessel "David" attacked the United States ironclad "New Ironsides," of 3,486, old American tons, carrying 20 guns, at anchor in the midst of the blockading squadron off Charleston. The "David" was a cigar-

shaped boat, 60 feet long, and about 6 feet in diameter, so far submerged that only about 10 feet in length of the hull was visible 2 feet above the water. A clumsy and dangerous craft in a seaway, she could attain a maximum speed of 7 knots an hour. From the bow a 60 lb. charge of gunpowder, immersed 6 feet, was projected on an iron bar to a distance of 10 feet, ignition being effected by an acid fuze, rendered active by a collision nearly end on.

Observe the elements of failure. A charge destructive enough if exploded in actual contact, but innocuous to a strongly-built ship, by the accidental interposition of seven or eight feet of water, yet held near enough to the operating vessel to place her in imminent danger, either from the direct action of the explosion upon her thin sides, or from her being swamped by the falling columns of water; self-acting fuzes, so arranged as to necessitate the most exposed direction of attack, viz., the enemy's broadside; an acid composition, sluggish enough in its action to allow time for the boat to rebound after collision, the few feet required to render the explosion harmless; and last, not least, a commander and crew, who, having never fired their weapon before, were in greater terror of their own torpedo than the enemy need have been. Can we wonder that the conductor of this enterprise jumped overboard before the explosion; that his little vessel had her fires extinguished, and was nearly swamped; and that the "New Ironsides," though severely injured, was not compelled to return into port. The crew, deserted by their Commander, relighted the fires and brought their boat safely into harbour.

Four months of harassing false alarms intervened before a second attack was made on the outer blockading squadron, at some distance off Charleston. An outrigger torpedo was fitted to a little vessel, with a handworked propeller, and intended for submerging at pleasure—her own pleasure, however, not that of her crew—which had, moreover, proved the coffin of four different crews. With this vessel an attack was made on the United States' corvette "Housatonic," of 1,240 American tons, and carrying 13 guns, lying at anchor in the outer waters, and forewarned, a month previously, of such an assault. About 9 P.M. on the 17th February, 1864, when about 100 yards off, the boat was observed approaching; the corvette's cable was instantly slipped, the engines backed, all hands called to quarters, and small arms fired at the boat, but in two minutes the ship was struck on the quarter, and five minutes afterwards the "Housatonic" was at the bottom with 150 men clinging to the rigging. For the fifth time the Confederate boat submerged at her own pleasure, and buried her fifth crew, how, when, or where is not known. It is evident from this that unseaworthy vessels have no special advantages for torpedo purposes.

A month later, the United States' ship "Memphis" only escaped destruction by slipping the cable and going ahead, the movement of the propeller breaking off the outrigger. As the torpedo vessel had no means of rapidly substituting other outriggers and charges, it had to return to port unsuccessful.

Guard boats, steam and rowing, protected the blockading ships, which further kept their steam up, and in some instances cribs of

timber, nets, &c., were employed as protections. Yet, on the 9th April, 1864, the United States' wooden flag-ship "Minnesota," of 3,307 American tons, carrying 42 guns, was attacked at 2 A.M. in the midst of a large squadron off Newport Roads, Virginia. Profiting by past experience, an ordinary steam launch was employed, which escaped without loss from the fire of heavy guns and of musketry from the ships, as well as from the gunboats acting as guard boats; and, having a longer outrigger, from any ill effects of her own weapon. But the other fatal errors remained, viz., a 53 lb. charge, quite insufficient to allow for the interposition of seven feet of water arising from the rebound; the employment of sluggish fuzes; and the attack at right angles to the enemy's broadside. Hence the "Minnesota," though severely injured, was able to continue on her station. Having no means of rapidly bringing other torpedoes into action, the steam launch was unable to take advantage of the confusion which arose in the alarmed fleet.

Ten days later, the United States' steam frigate "Wabash," a similar ship to the "Minnesota," was attacked in the outer roads off Charleston, but took to flight on the early discovery of the approaching torpedo vessel. Slipping her cable, the "Wabash" escaped at full speed, opening a fire from her broadsides and from musketry, which in the darkness might have led to fatal consequences had friendly ships been near, but which left the torpedo vessel unharmed.

The fatal mistakes made by the Confederates in the employment of small charges, which required absolute contact at the moment of explosion, of self-acting fuzes which necessitated an attack nearly end on, and of short outriggers which imperilled the operators; of not providing means of rapidly bringing any number of fresh torpedoes into action from any part of the vessel, ahead, astern, or on the broadside; and of being unable to fire at will whilst the attacking vessel was stationary, are so obvious that we can hardly wonder that, during the last year of the civil war, they ceased to employ so bad a weapon, notwithstanding that so many of their larger ships were furnished with them.

The Confederates had no sooner ceased to employ torpedo ships, than the Federals, profitting by southern experience, took up this naval arm. Perceiving some of the disadvantages referred to, they discarded self-acting fuzes for their outrigger torpedoes, and adopted a simple trigger-line igniting arrangement, which admitted of the explosion being affected at the will of the operator, with or without contact; and they increased the length of the outrigger, which could also be recharged, but they introduced a new danger in a contrivance for disconnecting the torpedo, which is buoyant, from the outrigger before ignition. Thus the operating vessel may drift over its own detached torpedo, or the floating charge may be drawn towards the vessel by the action of pulling the trigger-line. Moreover, it is evident that the buoyant torpedo, when thus detached, is more likely to float up alongside the hostile ship than under her bilge, and is apt, therefore, at best, to be exploded harmlessly against the armour plates at the water line.

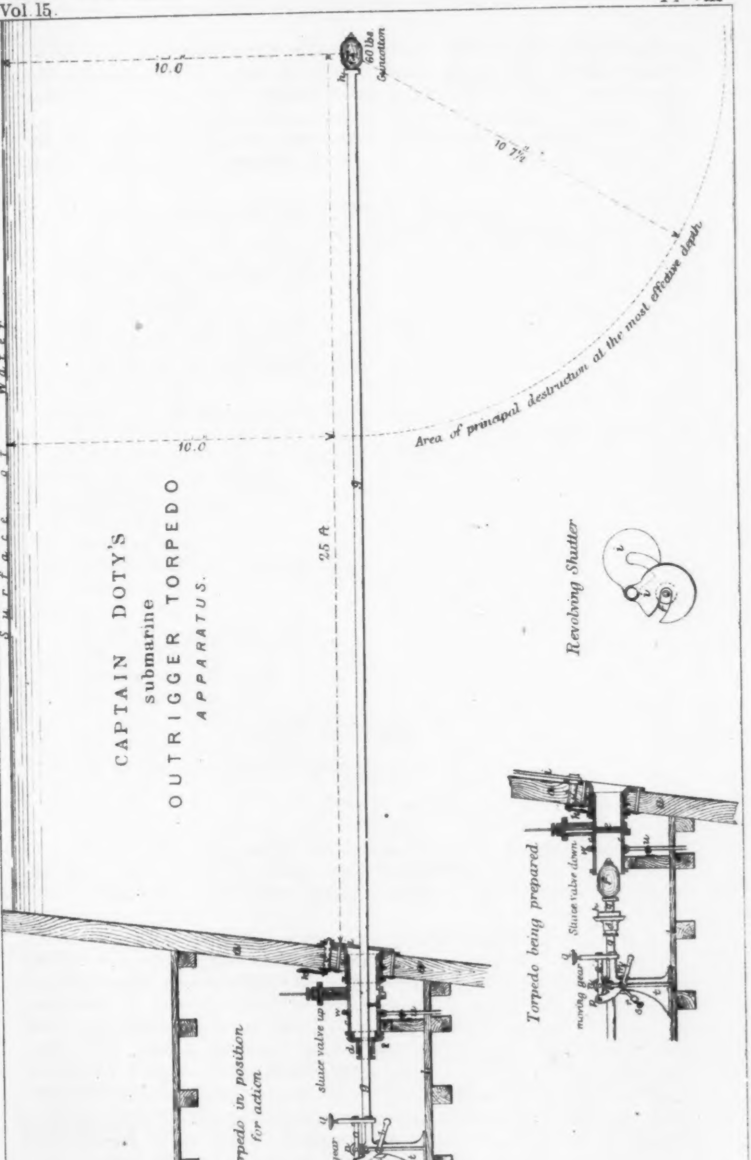
Other dangers were subsequently introduced in the special torpedo ship "Spuyten Duyvil," which was fitted with most ingenious and complicated machinery to achieve that which every seaman knows should be sedulously guarded against, viz., giving universal motion to the outrigger. The fatal consequences of an outrigger, held fast by machinery, being placed across the stem of a ship in motion is obvious to every seaman; whilst the vertical motion is, in the case of an outrigger projected from below the water line, quite unnecessary, and the apparatus for letting loose the torpedo before ignition fatal. I regret that Commander Barnes does not, as a seaman, recognize these objections so strongly as to dismiss the "Spuyten Duyvil" with less attention than he bestows upon this misguided effort of engineering skill.

A much more promising method of projecting tubular iron outriggers, with torpedoes affixed from the stems of ships horizontally, as far below the water line as practicable, is presented in the plan which Captain H. H. Doty has patented in this country. This consists of a metal cylindrical chamber, with sluice valve, fixed into an opening in the bow. The hollow iron outrigger is projected through a stuffing-box in the cylinder cover, and is only susceptible of longitudinal motion. By this simple apparatus, outriggers and their charges can be replaced, whilst the operators are preserved under cover. Though the plans, as patented, are excellent in principle, they would require much modification before practical application to the purposes of war. They should not be lost sight of by those to whom is committed the honour and the maritime safety of the country.*

Plate VIII. Submarine Outrigger Torpedo Apparatus.

Here are two different sections of Captain Doty's submarine outrigger torpedo. The lower one represents the torpedo being prepared, before it is projected from the bow ten feet below the water-line. The cylinder has a sluice valve in the middle, and is sufficiently long to contain the torpedo between the sluice valve and the cylinder cover. The tubular iron outrigger is passed through the cylinder cover, and screwed on to the torpedo, which is then placed in the inner part of the cylinder. The cylinder cover is then put on, the sluice valve raised, and the moving gear employed to project the outrigger horizontally in a line with the keel. A little back stay receives the inner end of the tubular bar. The electric wire for firing passes through the tubular outrigger, and comes out at the inner end or through a hole hole near the end. Though a simple and practical apparatus, sufficient strength has not been given to the several parts. The longitudinal thrust from the actual explosion is a mere nothing; therefore, as far as that is concerned, there would be no strain upon the interior part of the apparatus at all. What has to be considered is:—1st. That the 25 feet length of outrigger working up and down in a sea way would

* See "Specifications of Edward Thomas Hughes of Improvements in Submarine "Batteries, A.D. 1864, 30th January, No. 260, Letters Patent."


Surface of Water
10.0
60 lbs. Guncotton
10 7½
Area of principal destruction at the most effective depth
10.0
25 ft
CAPTAIN DOTY'S
submarine
OUTRIGGER TORPEDO
APPARATUS.
Revolving Shutter
Torpedo being prepared.
Sluice valve down
moving gear
Torpedo in position
for action
sluice valve up
moving gear

J. Jobbins

bring a great strain on the cylinder cover. And, 2nd, that in making the attack, the end of the rod might be run against the hostile vessel; and the back stay and cylinder cover would have a very considerable force to bear; therefore, the apparatus must be much stronger. The general principle appears simple and worthy of consideration; but I am not prepared to commend the details.

Fig. 1. Longitudinal section. Torpedo projected.
Fig. 2. „ Outrigger being prepared.
Fig. 3. Front view of shutter.
a. Bow of ship near the stem.
b. A deck below.
c. Iron cylinder 24 in. by 12 in. diameter.
v. Tube secured to ship's frame.
d. Cylinder cover and stuffing-box.
e. Sluice-valve.
f. Metallic case charged with 60 lbs. gun-cotton.
g. Tubular iron outrigger to project 25 feet beyond stem, 2½ inches external and 1½ inch internal diameter.
h. Union joint on torpedo.
i. Revolving shutter.
j. Pin of ditto.
k. Lever of ditto.
l. Winch handle of moving gear.
m. Lower roller „
n. Upper roller „
o. Lever of upper roller, *n*.
p. Fulcrum of lever, *o*.
q. Handwheel and screw.
r. Recoil back-stay.
s. Tightening screw of recoil back-stay.
t. Standard of moving gear.
u. Discharge water-pipe in cylinder, *c*.
w. Air vent „

A number of U. S. steam launches, originally designed for picket service, were fitted with simple spars working in crutches on the gunwales, their outer extremities being provided with detaching baskets for the torpedoes.

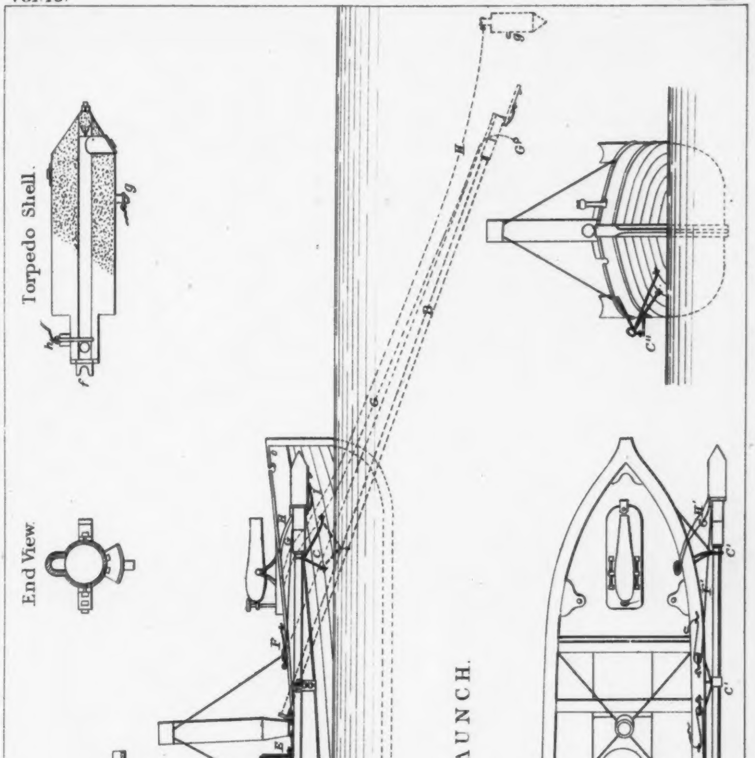
These boats carried the usual 12-pounder howitzers, and crews of twelve to fifteen armed men. Before ignition, the spar is rigged out and depressed, the crutches regulating the angle and distance. The elongated buoyant torpedo is then detached, a pull of the trigger-line withdraws a pin from the upper, or air-chamber, end of the case, and lets a spherical metal ball fall upon a percussion cap resting on a nipple at the lower extremity. A number of light-draught monitors, the displacements of which having been miscalculated were unable to carry their armament, were also fitted with outrigger torpedoes, and before the conclusion of the war the boats of ships-of-war were all ordered to be fitted for service with similar weapons.

PLATE IX. UNITED STATES STEAM LAUNCH, WITH OUTRIGGER TORPEDO.

Here is a drawing of the ordinary United States' picket-boat or steam launch. The outrigger spar is shown in its ordinary position, and in that occupied in action. The end is fitted with a basket or scoop, of which an enlarged section is shown. The torpedo has an air chamber at one end, and a central longitudinal cylinder, at the top of which is the firing pin, which sustains a spherical ball. When the pin is pulled out, the ball falls on the top of a percussion cap and ignites the charge. The torpedo fits the basket at the end of the outrigger, on one side of which is a sheave through which a back rope leads, and passing round the crutch in the torpedo, is made fast at the other side. By pulling on the back rope, the torpedo is thrown out of the basket. Until ready for detaching the torpedo, its lug fits into a hole in the basket, and is retained there by a pin, which must be drawn out before hauling on the back rope, when the lug runs up the incline, and the torpedo is liberated from the outrigger. It is a precious dangerous arrangement to have your own torpedo floating about close to your own vessel. It should be held fast in a known position until it is exploded. The only damage then accruing would be to blow off six or eight feet of the spar, which could easily be remedied by having spare spars.

A.A.' Ordinary position of outrigger.
B. Outrigger in action.
C.C.'C''. Outrigger supports and guides on pivots.
D.D'. After crutch.
E.E'. Running-out rope.
F.F.'f. Detaching heel rope, score, sheave and cleat.
G.G'.g. Securing-pin rope, pin, lug, and hole in scoop.
H.H'.h. Trigger line, pin and igniting ball.
I.i. Scoop or basket at outer end of outrigger.

As the seas had been swept of Confederate ships before the torpedo became an established Federal naval armament, there were few opportunities for its employment; nevertheless, the Federal Navy had the credit of making the first attack with an outrigger torpedo ship upon a hostile ironclad underweigh. The attempt, though unsuccessful, is not without interest. The Confederate ironclad casemated ram "Albemarle," descending the Roanake River, had beaten off the Federal squadron, contributed to the fall of Plymouth, and obtained the control of Albemarle Sound. Eight United States' steam-vessels proceeded to recover the loss, and, failing to plant certain stationary torpedoes at the entrance of the river, to prevent her exit, the "Albemarle" and two unarmoured consorts issued forth on the 5th May, 1864, to the fight. A well-contested action ensued, in which it was vainly attempted to destroy the slow but invulnerable ram by running her down, and to impair her motive power by fouling the screw propeller with nets laid in her track. Being a low freeboard ship, she was nearly over-ridden by a smaller wooden vessel, which succeeded in planting her forefoot on the low deck of the ironclad.



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The United States' paddle-wheel steam ship "Miami," of 730 American tons, armed with 13 guns, was fitted with a torpedo, projected from the bow, which the Commander was ordered to attempt to explode under the "Albemarle," but, says the Commander of the squadron, "for some cause yet unexplained it was not done." The failure was attributed to the unhandy character of the ship, and if a self-acting torpedo, requiring a collision at right angles to the broadside, was employed, the reason assigned is not unlikely. But as neither officers nor crew had ever fired a torpedo before, and could not tell what effect it might have on their own nerves or vessel, and were equally without experience in both the manipulation of the apparatus, and the manœuvring of a torpedo ship, it would not be surprising if they were afraid of their own weapon.

The only subsequent opportunity the Federals had of applying this arm offensively, was with one of the steam launches in the destruction, at 3 A.M. on the 28th October, 1864, of this same ironclad, whilst fastened alongside the wharf at Plymouth, eight miles above the mouth of the River Roanoke, which is about 200 yards wide at this point. The "Albemarle" was protected by guard vessels placed a mile lower down the river, by lines of pickets on the banks, and by logs of timber, &c., around her, about thirty feet from her side. Though discovered by the "Albemarle," Lieutenant Cushing, U.S.N., gallantly charged the surrounding logs at right angles with his steam launch, under a heavy fire at fifteen feet range, breasting the logs in some feet. Whilst the boat's bow rested upon the boom, the attention of their opponents was diverted by a discharge of grape shot, and the torpedo boom was lowered over the logs and under the "Albemarle's" overhang. The torpedo was then detached and the trigger-line pulled, making a hole near her water line, from which the "Albemarle" sank in a few minutes, the town of Plymouth capitulating three days after.

This complete success must not blind us to the faults of the weapon employed. Had not the "Albemarle" been built with an overhang which caught the buoyant torpedo as it attempted to rise to the surface, and had not the explosion taken place in contact, or within seven and a-half feet, the ironclad might have escaped destruction—the charge being, as is supposed, only about 60 lbs. of gunpowder. The steam launch was, morever, swamped by the falling water, whether in consequence of detaching the torpedo before pulling the trigger-line or not, is unknown. Of the fifteen persons composing the crew, two were supposed to have been killed or drowned, eleven made prisoners, and two, including Lieutenant Cushing, escaped. This was a small price to pay for an ironclad ship, which had successfully defied a wooden squadron, and for an important strategical position which had held out against an army and small fleet.

No further opportunity for employing this weapon offensively occurred during the remaining months of the war; but the practicability of a much wider development of this mode of attack was considered to have been established.

Hazardous as such enterprises undoubtedly were, they were not so much so as the cutting-out expeditions of former times; and in no

single instance did a torpedo vessel ever suffer any damage from the offensive powers of her antagonist, even though single boats penetrated into the midst of whole fleets, with their steam up and guns manned, and surrounded by guard boats watching for their approach. If instead of single attacks, we suppose a number of ordinary ships' boats and small steamers, provided with outriggers for projection from the bow, the stern, and the broadside, armed with 60 lb. guncotton charges, ignitable at will, and sent in at night, either amongst a blockading squadron, or a fleet at anchor in its own harbour, which is unprovided with similar weapons, what intense confusion and destruction would be caused! Almost every defensive action would add to the danger to friendly ships in a crowded roadstead, whilst well-handled boats, bristling with outrigger-torpedoes, could not be safely boarded or run down in any direction by hostile vessels, and would find safety in the closest quarters with their largest antagonists, which could scarcely defend themselves at night, except by torpedoes, against boats momentarily under their bows or counters. Surely such an auxiliary arm is not to be despised, whether used against or by our Fleet; whilst the tactics, offensive and defensive, involved in its adoption, are deserving of study and practice in times of peace, that Officers and seamen may gain the experience requisite for success in war.

Night-attacks in anchorages are but a small part of the probable applications of this new arm to naval warfare. It is obvious that day-attacks in the open sea cannot be made by open boats against large ships in motion. True, suggestions of this kind have been entertained, even in high places, but they are too puerile to deserve the consideration of nautical men. In the late American conflict, both sides fitted steam-ships of large size with outrigger-torpedoes, and in one case an unsuccessful attempt was made to employ this weapon in a general action. That more was not accomplished by the large ships thus prepared, arose chiefly from the obvious defects in the apparatus—defects which have long ago been obviated by ourselves. We have no official information from the United States enabling us to form a judgment as to the limits of speed and of rough water in which an outrigger could be carried, but I have been assured by a Confederate Officer, that a fast steam ship performed the voyage from Wilmington to Nassau in bad weather, with a tubular iron outrigger projected from her stem. Many of our officers on foreign stations would, in the ordinary course of service, gladly carry out series of experiments, without a fraction of expense, which would determine the best means of temporarily securing outriggers projected from various parts of the ship at the required depth and distance, and the limits of speed and weather in which they could be employed. Such simple experiments would be far more worthy the name of torpedo-instruction than that which is so-called in the gunnery ships,—the information would at least be derived from practical experience at sea.

Let us suppose this information obtained, and that each ship in the Fleet had a quiver full of outriggers on the forecastle and another on the quarter-deck, with the means of projecting them singly from the

bow or fore chains, and from the stern or mizen chains, with a torpedo crew of six or eight men, under an intelligent officer, at each end of the ship, whilst a third crew of six or eight men and an officer had charge of Captain Harvey's diverging towing-torpedoes for either quarter. The torpedoes to be only ignitable by electricity, and therefore perfectly safe to handle, as well as to one's friends. These would form an auxiliary armament of which there would be little or no outward indication, and which could be brought into use in a moment should opportunity occur, without, in the interim, interfering with the action of the ram, or of the guns.

Let us further suppose that only one of the hostile fleets carries this additional armament, and that the Commander-in-Chief holds, with Admiral Tegethoff, that "the ram will be the future umpire of naval contests," and assumes the offensive. By a sudden action of the helm the ramming may be avoided (excepting by the low-freeboard vessels), and the attacking ships will then pass close along the broadsides of the enemy, exchanging gun shots. If they pass close enough, and at sufficiently diminished speed, the bow outrigger or the swinging-boom may be dropped, and a 60 lb. charge of gun-cotton immersed ten feet, exploded within eleven feet of the enemy; or should the speed or distance be too great, the Harvey towing-torpedo, which requires great speed and can be used with 300 yards of tow-line, may be launched from the inner quarter and, starting off at an angle of 45°, be brought into collision with her counter. In either case, the failure to ram would be effectually retrieved by the instant sinking of the enemy.

The second line of attacking ships, following at that full speed which suits best the Harvey towing-torpedo, would be prepared to employ that weapon against the enemy's vessels, none of which are likely to present their broadsides a second time to be rammed. Whilst even the small craft of the attacking fleet might follow in the wake of the iron-clads, with divergent torpedoes towing four points on either quarter. If three such lines of ships failed to decide the action by their impetuous onset, it could only be from lack of experience in the tactics essential to the full development of this valuable auxiliary. But, as the outrigger torpedo does not require motion at all for its successful employment, and is best favoured by slow speeds, whilst the Harvey towing-torpedo courts high velocities, it is evident that the first onset does not exhaust the uses of these weapons; but that they may be usefully employed under almost every contingency which brings hostile ships within torpedo range of each other.

Or, as general actions may be uncommon, let us suppose a slow ship provided with this additional armament, overtaken at sea by an otherwise superior force. The enemy, unaware of aught but her guns, approaches in confident anticipation of surrender in reply to the challenge shot. Speed is slowed, apparently in preparation for hauling down the flag if it has been hoisted, and the vessels close under pretty equal conditions of speed; then, by a quick action of the helm and engines, before any torpedo apparatus is shown, the bow is brought into contact, or nearly so, with one of the hostile ships, or a Harvey

diverging towing torpedo, is shot out three or four points on the quarter to any distance under 300 yards, and there is, not only one less opponent to account for, but a wholesome respect infused into the others, which, if rapidly utilised, may give time for even a slow ship to further reduce the number of her opponents. In that reversion of the chase which might follow, the hostile ships would be restricted to distant firing, in which the torpedo ship would be no worse off than if she had not been provided with an auxiliary apparatus by which she had already accounted for some of her opponents.

The preponderance of offensive power afforded by such an auxiliary weapon is so evident, that its employment will not long be confined to one side in a maritime war, and a new exercise of seamanship will be developed, when both sides are similarly armed. The first obvious effect of the great dangers involved in a near approach to a hostile ship, however seemingly weak, would be to put a stop to ramming and boarding altogether. To attempt to ram or board, even, a ship deprived of motive power, but bristling with outrigger-torpedoes, would be so hazardous an enterprise, that only the Harvey towing-torpedo or gunnery could be employed for her destruction or surrender.

II. Though Commander F. Harvey's divergent towing-torpedo has not been put to the test of actual war, we have this great advantage in forming an estimate of its value, that unlike the plaything called an outrigger torpedo, in the "Manual of Gunnery for H.M.'s Fleet," Captain Harvey's experiments have been conducted with the actual apparatus which has been supplied to various navies for the purposes of real war; and it is so simple in its construction and self-evident in its manipulation, that any intelligent seaman can easily comprehend it, though much skill and experience will be called forth in the handling of the ships, to determine the great variety of applications of which it is susceptible.

The towing torpedo is essentially a sea-torpedo, and can, undoubtedly, be used in any weather and at any speed exceeding four or six knots. This last proviso marks it as less applicable than the outrigger torpedo for boat service, and for the ordinary conditions of harbour or night attacks, when explosions must often be effected whilst the attacking vessel is stopped, or moving very slowly. The circumstance that it can be used in all weathers, at all greater speeds, and at a distance of at least 300 yards, marks it out as especially valuable just where the outrigger fails. Thus every sea-going steam-ship, man-of-war, or mercantile vessel might, in the event of a maritime struggle for existence, be armed with such a weapon, in addition to her other powers of resistance.

The "Excellent" class book "on electricity," by Commander Fisher, proposes that ocean torpedo warfare should be confined to a special class of vessels, of 150 to 200 tons, and Captain Harvey adopts a similar view, viz., that peculiar vessels should be built for the service of this arm. From these views I most entirely dissent. There is nothing whatever in a small tow line attached to an angular diverging otter,

not larger than a Dell's zinc powder case for ship's magazines, to call for a special vessel not yet designed, which will never be where it is wanted; nor is there anything to prevent its employment by any and every vessel capable of going at least six knots per hour. The mercantile marine posseses many vessels of the slight scantling, great speed and quick turning powers, required by Captain Harvey; and if those do not meet his wishes, I hope none other of such a class will be specially built for such an exceptional use. Similarly, I wholly dissent from Captain Harvey's first proposition, that his sea-torpedo should only be used at night. In the open sea, hostile ships do not always wait each other's special convenience as to the hour when actions should commence; nor is it easy to find a ship at night, or to see one far enough off to get up the high speed required for Captain Harvey's attack. And I dismiss altogether the chimerical supposition that a torpedo vessel must always be of greater speed than her antagonist: as also that she is not to run all the risks of sustaining vital injuries from the weapons of her opponents; and that she can dispense with the protection of heavy guns. Captain Harvey claims that his is essentially a sea torpedo, and it must be part of that claim that it shall meet the ordinary conditions of ocean warfare. The weapon itself is quite capable of doing this, but rather as an auxiliary offensive arm, carried by all armed ships, as well as by merchant steamers for their own defence, than by its exclusive employment by a few vessels of peculiar construction, which have yet to be designed.

Captain Harvey's towing torpedo is a narrow, angular, water-tight case, with a removable heavy iron keel, by which its immersion is adjusted to various speeds. It will contain 76 lbs. of gun-cotton, or the same quantity of the more powerful explosive employed by Captain Harvey. This charge may be regarded, if well immersed, as a heavy one, inasmuch as explosion can only take place when in actual contact; though, on the other hand, it is very liable to occur against the armour-plates at the water line. The ignition is effected by chemical means, acted upon by levers when in collision with an opposing body. A safety key and line is provided, to be withdrawn, whilst in tow, immediately before collision; and a further safeguard is furnished by cutting the tow line, when the torpedo will run off the line by its own weight, and sink to the bottom, leaving its buoy on the surface, with the tow rope attached.

The first essential quality of a good torpedo is absolute safety, not only to the operators, but to friendly vessels when engaging in a general action, in which friend and foe are commingled. This, many practical officers, who have officially conducted or witnessed the experiments, believe Captain Harvey has attained by the safety key, and by sinking the torpedo on cutting the tow line. The whole arrangement is certainly simple and sailor-like, and it might be difficult to obtain more safety without sacrificing simplicity. Arrangements have, however, also been made for explosion by electricity, which, if they include self-ignition and the means of testing fuzes, would, in my judgment, ensure a greater degree of safety.

PLATE X. COMMANDER HARVEY'S DIVERGENT TOWING-TORPEDO.

a. Starboard torpedo ready for immersion.
a'. Port torpedo making contact.
b, b'. Wire tow-lines.
c. c'. Tow-line reels, with brakes.
d. Starboard safety-key line.
d'. Port safety-key line.
e, e'. Safety-key line reels, with brakes.
f, f'. Lowering ropes attached to tow-line blocks.
g. Torpedo-buoys.

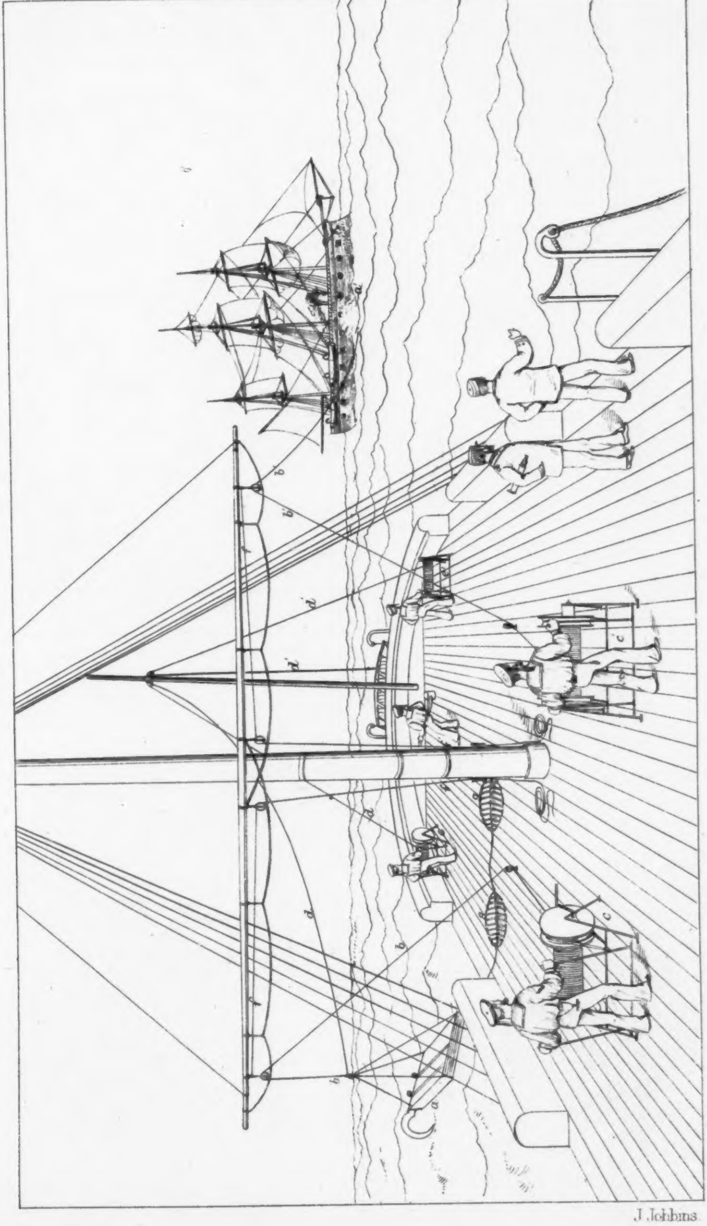
The distinctive feature of Captain Harvey's towing torpedo, is the divergency obtained by the angular narrow form experimentally determined, and by the arrangement of the slings through which the towline from the buoy is rove, after a stop-knot has been worked on it. Different shaped torpedoes are provided for the starboard, and for the port quarters, which change sides if used, with stern motion, from the bows. To keep the bights of the tow-lines out of water, they are led through blocks on their respective sides, about 20 feet above the surface, and then worked on hawser reels fitted with brakes. The safety-key lines are led through blocks high up on the ensign staff or gaff, and worked on reels, which are also furnished with brakes.

Immediately before the explosion is to be effected, the torpedo is hoisted out by its own tow-line, the buoy being first streamed. It is then veered about 100 to 150 yards, without altering the speed of the ship. The torpedo thus tows upon the surface, at an angle of 40 to 45 degrees, so long as a high speed is maintained; but if a speed of less than six knots be anticipated, a less weight of iron keel is attached. Skilful manœuvring is required to tow the line across the path of the hostile ships, at which moment the safety-key is withdrawn, and the brake, which retains 150 yards of line in reserve on the reel, is suddenly relaxed, causing the torpedo to sink to the extent of the buoy rope, and the line to pass under the vessel's bilge or keel. The brake being again arrested, contact is made, and the explosion effected.

Towing a line of 150 yards, diverging 45 degrees on the quarter, under a vessel at anchor, is obviously a very simple operation if a speed of more than six knots can be maintained.

Attacking a ship at sea which must be approached end-on, the torpedo ship would probably launch her weapons on both quarters, at their fullest divergence, and one or other would be towed across the stem or stern, as circumstances might demand.

When chased by a superior force, and the chaser had approached a little on one quarter, within reach of a lengthened tow-line, the proper diverging torpedo would be launched astern with the line so slack that all but the buoy would sink in the wake. The moment the torpedo was opposite to the enemy's broadside the line would be checked, and the torpedo would diverge against the ship and explode. In this case the explosion would evidently take place against the armour-plates at the water line. But the destructive action of gun-cotton



J. Jobbins.

ignited by detonation, when employed without tamping or envelope, justifies the supposition that 76 lbs. of that material would inflict vital injuries to the ship at the back of the iron plates. Until this supposition is, however, verified by experiment, skill and experience should be exhausted to prevent the explosion taking place at the water-line. Probably the requisite submersion would be better obtained, in this case, if the divergence were made to take place astern of the enemy, and the line then quickly hauled in.

The official trials made at Portsmouth and Devonport, show that by a skilful use of the brake, the tow-line can be readily dipped under the bottoms of ships under weigh or at anchor; that the igniting apparatus is effective; and that the explosion can be made to take place several feet below the armour plating. But it is evident that such skill is only to be obtained by practical experience, and that if officers in command are to acquire this art, it must be on the bridge at sea, and not merely by hearing from others that the apparatus has been seen in the museums of the gunnery ships.

III. I am not aware of any submarine boat or locomotive torpedo with self-contained motive power worthy of consideration for the purposes of war, except perhaps those suspended from floating bodies, and dependent upon the tide or current for their progress, and hence called "drifting torpedoes." Though strictly speaking offensive weapons, drifting torpedoes are so easily intercepted, that their successful application against ships must be the result of surprises which ought not to occur in war. Drifting torpedoes might be useful when used against floating bridges, booms, and other wide objects. The best fuzes for them, known to me, are those devised by Captain C. A. McEvoy, formerly of the Confederate Torpedo Bureau, and now of the London Ordnance Works, who has not only great experience, but a most practical and fertile ingenuity in the essential constructive details of every variety of torpedo apparatus.

The chief difficulties in the way of submarine projectiles are:—

1st. To acquire and retain adequate velocity.
2nd. To maintain an equable depth of immersion.
3rd. To preserve the original line of direction.

Even elongated shell fired with large charges from heavy guns, retain these qualities for only about 30 or 40 yards, whilst their useful penetration ceases at as many feet. Submarine rockets of whatever construction, have uniformly failed to meet these conditions.

The most promising of such schemes of which I have any knowledge, is that of Messrs. Lupin and Whitehead, whose experiments in the Medway have lately been reported in the newspapers.

I understand their rocket-torpedo to be a cigar-shaped case with a screw-propeller worked by compressed air, and provided with what is, I suppose, a horizontal rudder. By a peculiar arrangement, in which the whole secret consists, the torpedo, when liberated from the attacking ship, at once dives to the depth it is set for, and maintains that immersion throughout its progress. This attainment is certainly a

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very large stride in a direction in which many persons have previously laboured in vain.

But the velocity attained is said to be only eight or ten knots per hour or 150 feet per second, which, for a projectile passing through a dense medium like water, and aimed at a distant vessel in motion or in a tideway, is obviously far too low.

Moreover, it is the property of such a rocket to start at a low velocity, and, whilst acquiring speed, it is more likely to diverge from its path than a projectile, the initial velocity of which is its greatest.

Even should the requisite initial velocity ever be attained, great nicety must be employed in aiming projectiles through a dense medium like water, which would greatly intensify the smallest error in the original direction.

For these reasons, I do not attach much value to self-contained powers of locomotion in submarine projectiles; and I believe that progress must rather be looked for in modifications of the outrigger, and the towing torpedoes, which are free from complicated mechanism, simple in their application, and, above all, safe alike to the operators and to friendly vessels.

In conclusion. Let us not be lulled into a false naval security, by the essentially military character of the present and former Continental wars, and the consequent absence of enterprise in foreign navies.

There are many Officers of the United States' Navy who could readily have fulfilled a contract to supply torpedo apparatus to every steamship and boat in the German blockaded ports, and to render the German waters untenable to the French fleet. If our own Navy could not furnish similar men and better material, it is not that the old spirit of hardy enterprise is waning, but for lack of that knowledge which is shelved in confidential blue books, or to be obtained by systematic experiment, and of that practical experience in torpedo manipulation and tactics, which alone can give well-grounded confidence in war. On the other hand, let us not be deceived by the lack of torpedo enterprise on the part of the French. Their fleet was wholly unprepared for this conflict; and ere sufficient time had elapsed to supply the needful material, the Imperial armies had collapsed, and the struggle for national existence became so evidently a military question, that no special attention could be diverted to the Navy. Moreover, the supremacy of the seas being undisputed, France is able to maintain its communications with its foreign bases of operations not only undisturbed, but unthreatened; and no further military advantage could be gained by naval torpedo enterprise within the enemy's ports. The French fleet is fulfilling every requirement of the national situation. It is from the German Navy that we might reasonably have expected instructive examples of aggresive torpedo warfare. Young and weak as is that rising naval power, without that history and those traditions which create the *morale* and nerve the heart of a great service, it has a large nursery of prime seamen, brought up in our own mercantile marine, far superior in ability and moral conduct, and, consequently in endurance, to the great bulk

of those British merchant seamen who must, whatever be their physical and moral infirmities, form our chief reserve in war. The same stubborn determination and fixity of purpose which has organized an ever-conquering army, might, with the German seamen of the British mercantile marine, create in a few years a naval force demanding our respect, " foemen worthy of our steel."

Though we may not fear such a foe, even acting in alliance with other maritime powers, yet we cannot afford so to despise him, as to allow him either a manifest superiority of weapons, or a greater experience in their practical application to the purposes of war.

When this nation is called upon to occupy the present position of France, and to fight for national existence, the contest must be decided on the high seas. Should we be swept from thence, our island may be invested, after the example of Paris, and starvation become a question of time.

If we would be prepared against all comers, it is not sufficient that there should be in the pigeon-holes of the War Office or the Admiralty, learned blue books with detailed suggestions for the construction of the best descriptions of weapons. Of what avail will be the best of arms which only exist on paper, against, it may be, much less effective ones, but which exist in bodily shape and are employed by enemies who have been carefully taught how to handle them. Must disastrous reverses be sustained by the employment of perhaps a much worse form of torpedo against ourselves, before we begin to construct our own? On the contrary, officers and seamen should be in training during peace with the arms they will be called upon to wield in war. Without such practical experience, the Navy may find itself at the outbreak of a naval contest furnished with strange weapons, the use of which may be vaguely understood, and in which it may have no confidence. The first practical lessons may have to be learnt in the presence of a more far-seeing enemy, and British pluck be sorely taxed to make amends for administrative sluggishness.

That such a fearful struggle may long be averted must be our most anxious prayer; though, should it come in my day, I may be permitted, in taking leave of my brethren in arms at so early an age, to express the profound regret with which I contemplate the artificial necessity which will prevent my sharing with them what will then be the labours, the responsibilities, the dangers, and the honors of British seamen.

Admiral Ryder: I should like to ask what is the strain necessary to pull out the safety key of the Harvey torpedo?

Mr. S. J. Mackie, C.E.: I should like to say a few words upon Captain Harvey's torpedo. I think a remark fell from the lecturer, which, in the first place, requires distinctly to be noticed. I understood him to say that Captain Harvey intended to use his torpedo solely at night. I am myself under a different impression. I think that Captain Harvey's idea upon that point is that it would be used with the greatest advantage at night under cover of darkness, but that there is no possible objection whatever to using it in the open daylight. Any one can see that it is difficult for any ship using heavy guns to hit a rapidly moving object at close quarters. Any one who has travelled down the river, and seen one steamboat pass another at even moderate speed, will feel how difficult it would be to train a gun rapidly upon it, and how still more difficult it would be to do so if the speed were swift. I think this

difficulty would hold good with regard to Harvey's torpedo in sea-service. I think any light unarmoured vessel, or any other vessel using the torpedo would have a very fair chance of escaping unhurt before her antagonist could bring a gun to bear. I should also like to make a remark upon what has been said with regard to Captain Harvey's having the desire for special vessels for this torpedo service. As far as I know Captain Harvey's ideas upon the subject, he considers his torpedo to be equally applicable by any class of vessel whatever, from the largest ironclads to the ordinary merchant-ship. But I think the idea of his preferring small vessels, or special vessels, for these weapons has arisen in this way: that small vessels being of very little cost, might be most advantageously employed against large vessels of very great cost. Also that in the manipulation of this torpedo, the power of rapid turning which would be developed by small and swift vessels would be of serious advantage in enabling such vessels to hit their antagonists. I would also make another remark with regard to the increase of size of these torpedoes, when larger charges are employed. The torpedo on the table, I apprehend, has a 28lb. charge. The size of a 86lb. charge torpedo would not be three times the size of this one, probably only some inches larger, say one foot larger. You will comprehend that as the torpedo case is increased in size, so the cubic capacity of the charge-chamber is also increased in every direction, therefore you would get a very large additional charge in a torpedo not so very much larger to the eye than the one before us. I might also remark, for I have seen something of torpedo experiments myself, upon the very great advantage that there is in towing a torpedo against the ship's side. The vessel runs up at full speed, strikes her adversary, and passes away at full speed. With the outrigger system, a small boat or a special vessel is brought into dangerous proximity to the vessel attacked. I do not mean to say that the launch, or small vessel, cannot get out of the way of the effect of the explosion of the torpedo it has discharged. But the enemy that is hit may cause a great deal of damage to the attacking vessel when it is brought up so close. The falling of spars, the explosion of a boiler, or the explosion of a powder-magazine, may occur; or even the falling over of the column of water spurted up by the torpedo may be so sudden that the attacking vessel might not be able to get clear from swamping. With regard to the fish torpedoes, the other class of under water weapons, I think myself there is a great difficulty in their application. I saw the fish-torpedo tried upon the "Aigle" from the apparatus fitted on board the "Oberon." I felt at the moment that there was a very grave disadvantage in attacking in that way. The "Oberon" had to approach the "Aigle" in a direct line upon the broadside. It was quite clear that while coming up thus for some distance in the day time, the attaking vessel would, of course, have been exposed to the fire of the enemy's ship. When the "Oberon" discharged the fish-torpedo she had to arrest speed, and was brought almost to a dead stop, and then to fire at a range of some three or four hundred yards. While she was being brought up to that position of rest she was a fair target, and would have been hit again and again. Another thing that may be said of submarine torpedoes is, that it is absolutely necessary for hitting a ship with them to have a knowledge of the currents going on in the sea at the time. You must judge of the distance of the ship, you must judge of the effect of those currents in carrying your torpedo in one direction or another, before you can ensure striking a ship, even when you attack her on the broadside. It seems to me that a ship at anchor, and much more one in motion, would have a fair chance of escaping. A vessel would hardly have a chance of escaping being hit by Captain Harvey's torpedo.

Captain DAWSON: You have referred to the Austrian torpedo, the Lupin, Minet, and Whitehead torpedo.

Mr. MACKIE: Yes, the Whitehead; but I speak of the fish-torpedo, and similar weapons, as a class. I do not wish to refer to Mr. Whitehead's in particular.

Captain DAWSON: But to that class of torpedoes.

Mr. MACKIE: To that class.

Captain HANSON (of the Volunteers): May I be allowed to put a single question? How is Captain Harvey to get this most destructive torpedo under the bottom of the enemy by that towing apparatus. I have no doubt if he gets it there, and explodes it at the right moment, that he will blow the ship all to pieces. But that

appears to me a matter of particular difficulty. Surely the enemy would be aware of the character of the attacking vessel, and would yaw and steer about to avoid this destructive apparatus under water. To judge of distance with heavy guns through the line of air is not a difficult thing, but to send something under water, and not to know exactly where it is, seems to be to me a most difficult thing. I beg to thank Captain Dawson, as far as I am concerned, for his paper, but that seems to me to be the difficulty, how to get it under the enemy's bottom.

Captain SCOTT, RN.: I entirely concur with what Captain Dawson has stated, as to the difficulty Naval Officers have in acquiring information. It is the fact that their instruction is not what it should be, and I think calling attention to it in such a way is extremely valuable, especially with the lesson which we are being read over the water. We are accustomed to deal with questions piecemeal. One man looks at them in one light, and another in another, therefore the great divergence of opinion. What we want is to consider all these questions as a whole. I cannot follow all that Captain Dawson said about the torpedo, because I am not thoroughly versed in the subject. But I entirely concur in what he has said, and I thank him myself for having given me a great deal of instruction this evening.

The CHAIRMAN: Perhaps Captain Dawson will answer the two or three questions that have been put.

Captain DAWSON: I have to thank those gentlemen who have kindly taken part in the discussion. I am extremely sorry that they do not disagree with me far more, for I believe we arrive better at truth by the collision of minds than by uniform agreement. Admiral Ryder has asked me what strain is required to withdraw the safety key? I have looked over the instructions in "Tactics of Harvey's Sea Torpedo," drawn up officially by Captain Harvey, and I find he does not state the actual strain. He says that to withdraw the safety key, "it is only necessary to hold fast the safety-key line," by pressing down the brake of its reel, "and to veer the tow rope, when the towing strain will be brought on the safety-key line, which will break the stops and withdraw the key." Perhaps Captain McEvoy may know the strain.

Captain McEVOY. I am not able to tell the exact strain. The strain is regulated by a stop, which consists of several strands of thread, the number being proportionate to the resistance required. I imagine the strain would be somewhere about 20 lb. or 25 lb., but it may be increased or diminished at pleasure.

Captain DAWSON: I quite agree with Mr. Mackie in what he said with reference to the rocket or "fish" torpedo, but I do not at all think that any good will come of submarine rockets. He takes me to task with reference to Captain Harvey's proposed night attacks at sea. Now I hold in my hand the official book of "Tactics of Harvey's Sea-torpedo." The very opening line is this:—"Torpedo vessels should, "as a rule, attack under the cover of darkness; of necessity only should they attack "in the light of day." "In the employment of torpedoes it would, therefore, be "exceedingly indiscreet, indeed culpable conduct in an Officer, when about "to attack his foe, if he were, through impatience, not to avail himself of so "advantageous an opportunity, by which his vessel could avoid the risk of being "damaged in her top-sides, or possibly in some vital part of her hull or machinery." In another part he says:—"In conclusion, it should be stated that a dark night and "tempestuous weather are in favour of the attacking torpedo-vessels, and these con-"ditions are especially advantageous when attacking large, long, unwieldy vessels, "and the greater the number of them together, the more easily can they be disabled "or destroyed." Now, I speak in the presence of practical seamen, who I have no doubt can verify what I am going to say, which is, that in the open ocean in dark tempestuous nights, to find a vessel that does not want to be found, is an exceedingly difficult operation, and that if you saw such a vessel a quarter of a mile off, you cannot, within that distance, get up the speed which this torpedo requires in order to its successful application. Night attacks can only be made against ships at anchor, whose whereabouts is nearly known, and then the outrigger-torpedo would be the weapon preferred. I still stick to the text that I started with, that both the outrigger and the towing torpedoes are capable of being employed by every ship-of-war; that the speciality of the towing torpedo is its use at sea, and that if it is to be

an open ocean torpedo, it must fulfil all the conditions of ordinary actions at sea, which do not include attacks in dark nights; that it can do. Captain Hanson has asked me a question as to getting the tow-line under the bottom of a hostile ship.

Captain HANSON: The torpedo.

Captain DAWSON: If the line can be got under the bottom, the torpedo, of course, follows the line. As the torpedo tows on the surface, and is only 150 yards off on the quarter, it is easy to see what should be done. I have myself seen a few experiments with the Harvey torpedo, and I have read the official reports of the more recent and more perfect experiments made at Portsmouth and Devonport, in which both ships were under weigh. One ship tried to avoid the torpedo, and the other vessel tried to tow the line across her path and make contact. From the official tabular statement before me, I find that there was no difficulty experienced. Whenever the vessel attacked was at anchor, in an open roadstead, of course, it was easily done. There were six series of experiments against a ship under weigh, and they had no difficulty at any time. The line was always brought under the bottom of the ship by knowing that the torpedo was on the opposite side of her path, and then relaxing the brake suddenly, the towing strain caused the line to run off the reel very rapidly, and the weight of the torpedo sank that portion of the line which lay across the path of the ship, so that the vessel ran over the line, and, then, by arresting the brake again, the line was held under the keel, and the torpedo drawn under the ship's bottom. In the greater number of cases the explosion took place at considerable depths. In one series, five blind torpedoes were exploded in contact from twelve to sixteen feet below the water line. Eight other blind torpedoes were fired in another series, from ten to twelve feet below the water line. All the other series exploded perfectly. The manœuvre was practically accomplished at sea, and what one seaman can do another can perform, if he have practice sufficient to acquire the necessary skill.

Captain HANSON: No ship was firing; there was no smoke, no shot.

Captain DAWSON: No, they were most peaceful experiments.

Admiral W. KING HALL: I should like to make one remark. If the torpedo vessel is only 150 yards off, and our people have got their brains and their powder, I think our gunnery establishment would not be worth a pin if they did not make mince-meat of the vessel.

Captain DAWSON: In reply to Admiral Hall I would say that, as an old gunnery Officer, I ought to have a very great respect for guns, but it is a qualified respect. I know that the difficulty of aiming, when both vessels are in active motion of both helm and engines, is exceedingly great. You will remember that I started by saying that both outrigger and towing torpedoes might be employed by every vessel-of-war. So we must imagine a ship with the thick sides, and heavy guns, and fortified bows of the "Hercules" using torpedoes against a vessel with equally thick sides, and similarly armed in all respects except torpedoes. Other things being equal, the "Hercules," plus both forms of torpedo, ought to be more than a match for the "Hercules" without torpedoes. Moreover, what the Americans have done in war, British seamen could also accomplish. You might hit the "Hercules" with the best guns afloat a good many times before penetrating her armour, unless you struck it at right angles. But even if a ship were to have the topsides riddled, we must be made of very different stuff from our forefathers, if the chances of such riddling prevented a British Naval Officer closing with his enemy, knowing for a certainty that, once within torpedo range, he could instantly blow that enemy's bottom through her upper deck, and send ship and crew to the depths of the sea in less than two minutes.

The CHAIRMAN: I think that you will all agree with me in considering this a very excellent paper. I regret the discussion not having been fuller, which may be attributed either to the information on the subject being limited, or to its being "bottled up in those blue books" to which Captain Dawson has alluded. But I frankly own that, like many of my brother Officers, I am very superficially and imperfectly acquainted with the subject. However, we all know enough to be convinced that, whether for defensive operations in blockading or obstructing passages into harbours, or whether for offensive operations, as described by Captain Dawson, the

torpedo must play a very prominent part in future warfare. It is unquestionably the duty of those who have to train up Naval Officers to give them opportunities of becoming practically acquainted with a very new and somewhat complicated weapon to be used in any future wars in which we may be engaged. We give our best thanks to Captain Dawson for his admirable lecture; it is evidently a subject which he has thoroughly studied.

THE NAVAL HAMMOCK—ITS BUOYANCY AND USE IN SAVING LIFE AT SEA—IN CASES OF COLLISION, &c.

By Rear-Admiral A. P. Ryder.

It is well known that the boats of a man-of-war are, as a general rule, insufficient in number and capacity to save her crew, except in the smoothest water; also, that the largest and safest are stowed on the booms, from whence time is required to move them to the water—probably not less than ten minutes at sea in the daytime in fine weather—and of course under other circumstances, a much longer time.

In a recent instance of wreck from collision, viz., that of Her Majesty's ship "Amazon," within a few miles of the south coast of England, it was stated that if there had been any swell the boats could not have lived, so close to the water were their gunwales, and it is not probable that there was more than a day's provisions and water in them. Had the collision taken place further from England, say 100 miles off, probably half the ship's company would have been lost.

In cases of shipwreck when the vessel sank or burnt *slowly*, crews have often in times past been saved on rafts; but men-of-war were then supplied with numerous spare spars, yards, and a large number of casks, and it was a common topic of discussion among naval officers, "how a râft could be best and quickest made." But no one ever supposed that a raft or rafts for a large ship's company, capacious enough to efficiently supplement the boats, could be properly and securely put together, stored, and provisioned, in less than a few hours; and the most impromptu raft for, say twenty persons, could not, I feel confident, even with rehearsals, have been ready to shove off under a quarter of an hour. Rafts of sufficient size and buoyancy to supplement the boats are now out of the question, and for this reason: viz., that very few spare spars and yards are now supplied, and some of the latter are not unfrequently made of iron. Casks also are much diminished in number since the introduction of the canvas tanks for watering. Our usual resources for saving the lives of whole ship's companies when their vessels are lost, may be said to exist no longer. I am not about to attempt to suggest any substitute for rafts, I must leave that to the ingenuity of others; but I may mention that some very interesting papers have been read in this room on the subject; Perry's collapsible tubular life saving raft—has also been favourably reported on.

I wish to address myself to-night to one phase, and one phase only of shipwreck, be it loss by collision, fire, capsizing, or filling, &c., viz., that in which help is *near at hand;* and it is only necessary to float the ship's company for a very limited period (say for thirty minutes or an hour) after their vessel is no longer available for the purpose.

I desire principally to address myself to the case of *collision*, intentional or otherwise. Numerous cases of collision of men-of-war have recently been brought under our notice. I may mention the "Rey d'Italia" sunk off Lissa in a few minutes; all hands lost. A Russian frigate lost in the Baltic last year, by unintentional running down; several lives lost. An American man-of-war lost in the Eastern Seas; nearly all lives lost. The "Amazon," already alluded to.

There have been numerous instances in the merchant service of losses by collision. Several cases were reported in 1869 in the Board of Trade Returns, with much loss of life. In the merchant service, however, except in the case of passenger ships, the boats have generally sufficient capacity to save the crew in moderate weather, if only they can be cleared and lowered in time. If life-belts were universally supplied in sufficient numbers, and kept handy on board, and if the crew were practised by day and by night* in putting them on at short notice, there would have been no need for me to address you on this subject. But as the Admiralty only issue a sufficient number of life-belts for a boat's crew,† and as many merchant ships are not supplied with any life-belts at all, I have ventured to recommend a substitute, viz., the ordinary naval hammock, the remarkable buoyancy of which has been often noticed when one of them has accidentally fallen overboard.

In case of shipwreck at night when the men are in their hammocks, the number of lives that could be saved by this means would of course be seriously diminished; but those of us who are familiar with the remarkable quickness with which the men can lash up their hammocks at night when they are suddenly called to "general quarters," would not despair, if the ship did not sink for ten minutes, of many men being saved even by the hammocks they had been sleeping in a few minutes before.

In some men-of-war, especially when employed in the tropics, it is the custom for the watch coming on deck at night, to bring up their hammocks and stow them. I shall be able to give you evidence shortly that a hammock will support two men for a considerable time, and thus the hammocks already on deck might support for some time both watches in the water, two men to each hammock, and preferably the two men with opposite watch bill numbers, as this would prevent confusion.

* When I was Commodore of the Coast Guard, I obtained permission from the Admiralty to issue a life-belt to every Coast Guard man on the sea coast, and directed that they were to be exercised in putting on the belt with their eyes shut, so to familiarize them with the "feel" of the straps, and enable them to put the belts on at night. This was done at the suggestion of Captain J. R. Ward, Inspector of Life Boats, the inventor of the belt.

† It may be observed here, that if life belts were supplied for all hands, to the number of 700 for the crew of a first-rate, they would probably never be kept at hand, but be stowed away in some storeroom.

The inestimable value—in case of shipwreck from collision—of the buoyancy to be found in the naval hammock first occurred to me when I was second in command of the Channel Fleet a few months since. We were performing the perhaps useful, but apparently rather hazardous, evolution, which consisted in the columns passing through one another, each ship passing at full speed (for the boilers lit), close to her opposite ship. The speed of each ship was about 7 knots. The blow, if, by some accidental mistake of the helmsman one had struck the other, would have been similar to that given by a vessel going 14 knots to one at rest, and both vessels would very possibly have sunk in a few minutes, notwithstanding that they were compartmented.

There were numerous ships in company who would of course have steamed to the rescue, lowered their boats, and done their best; but I doubt if so many as half of the 1,400 or 1,500 men endangered would have been saved. It occurred to me that the hammocks, of which every individual has one (except certain of the officers, viz., those who have cabins), could save them *if sufficiently buoyant*, and that as their owners knew where they were stowed in the nettings, they were in the most convenient place possible for such a purpose. I have had the buoyancy of a hammock tested, and will give you the result presently. It has much exceeded my anticipations, and those of the numerous Officers who witnessed the experiments in Malta Harbour.

I hope that some of the readers of the Journal of this Institution on foreign stations will try the same experiments, and allow the men to witness them, and become familiar by practical proof (when bathing), with the buoyancy of their hammocks, and learn that it may be longest retained by not immersing any part of the hammock more than is absolutely necessary, as the water increases its pressure rapidly, and finding its way among the hair in the mattress, will soon expel the air and destroy the buoyancy.

The experiments may be usefully extended to show—

1. The *maximum* weight which a floating hammock containing no more than a bed and blanket will support, for say 30 minutes.
2. The various intervals during which a hammock will support weights less that the maximum from 1 pound upwards—(*a*) in smooth water—(*b*) when water is thrown over the hammock by, or as if by, waves.
3. How tightly the hammock should be lashed up to float longest—as it is conceivable that there is a mean degree of tightness, which is preferable—a loosely lashed-up hammock might float most buoyantly at first but become saturated soonest.
4. (*a*) How one man could best support himself with one hammock? and (*b*) how two men? whether in the latter case they should go to opposite *ends* of the hammock? or to opposite *sides*? and (*c*) whether they should, with the object of pressing the hammock down as little as possible consistent with obtaining full support, rest *hands* or *arms* on the hammock? (*d*) in the case of two men with two hammocks, would it be best for both men to be between the two hammocks, an arm over each?

5. Whether any material advantage would be derived from the set of hammocks slung for *sea* being prepared like a fisherman's jacket, viz., soaked in boiled oil, so as to be more impervious to water or
6. Whether if the ticking were made of a waterproof material, the hammock would support one man after the hammock and blanket were saturated, and for how long?
7. Whether cocoa-nut fibre would not be lighter than horsehair, and what are the relative advantages *quâ* buoyancy, and expense of horsehair—cocoa-nut fibre—and cork shavings.

I have included *capsizing* in the above list of casualties as a case when recourse to the hammocks might be useful, but I refer only to those cases of capsizing when the filling has been a *slow* process, as will often happen where, in a vessel on her beam ends, only one hatchway or scuttle admits the water.

Do not suppose for a moment that the hammocks would have been available in the sudden and extraordinary circumstances attending the loss of the "Captain." The time, midnight—the gale—the state of the sea—the unavoidable absence of prompt friendly succour, owing to the rain and darkness, all tend to isolate her case, and leave it on record as a warning and beacon to the constructors of ships, who will probably adopt as an axiom for the future that all vessels must, if possible, have sufficient self-righting power, even if thrown upon their beam ends, as all ships are liable to be at times. Several wooden men-of-war have been on their beam ends and righted.

There is no novelty in my suggestion for utilizing the bedding on board ship for life-saving purposes. It has been suggested frequently that the mattrasses and sofa-cushions of passenger-carrying packets should be stuffed with cork shavings, and I believe that the suggestion has been adopted in some cases; but I write under the impression that the buoyancy of the ordinary naval hammock—and the use it may be temporarily put to in cases of shipwreck by collision, &c.—have not yet been sufficiently appreciated.

I have already alluded to the case of a Russian frigate lost last year by collision

Admiral Boutikof, the distinguished officer who commanded the "Vladimir" in the Crimean war, and is now and was in command of the Russian Fleet in the Baltic at the time of the accident, informed me that he saw the frigate I have already referred to, sunk by accidental ramming in midday in a few minutes, and that many men were drowned, notwithstanding that ships were close to, and the weather was fine; but many were saved by the hammocks. After a few weeks the masts were removed, as they obstructed the navigation, although the hull was in over 20 fathoms water. In removing the masts, the hammock cloths were torn, and some of the hammocks *floated to the surface*, even after so long a submersion. I have lately learnt that the Russian beds are stuffed with cork shavings, and the incident is worth recording. I have learnt also that the Russian Government are known to have ordered a few years since a large number of Messrs. Pellew's patent cork mattrasses.

EXTRACT OF LETTER FROM COMMANDER BRIDGE, OF H.M.S. "CALEDONIA."

"*H.M.S.* '*Caledonia*,'
"*September* 13, 1870.
"*Malta*.

"Dear Admiral Ryder,

"Some time since you asked me to try an experiment with a "hammock, as to how many men it would float? Until our arrival "here this time, I have always been prevented, from one cause or "another, from carrying out the experiment. A well lashed up "hammock, containing only a bed and a blanket, supported for a few "minutes seven naked men, for a considerable time four men, and "would, I believe, have continued to do so for nearly an hour. Its "power of supporting small weights evidently seemed to be limited by "its own power of floating itself, which it would have continued to do, "I should say, for considerably over an hour.

"The officers who witnessed the experiments were, with myself, "astonished at the floating powers of the hammock.

"I ought to mention that the hammock itself was a new one, and "consequently was rather less pervious to water than an older one would "have been, but that probably did not add greatly to its floating capa- "bilities, though of course it did to some extent.

"Yours, &c.,
"CYPRIAN BRIDGE,
"Comr. R.N."

Captain Arthur Wilmshurst, commanding H.M.S. "Valliant," has kindly made further experiments at my request. The most trying test to which the buoyancy of the ordinary hammock can be exposed, appears to be that of suspending a weight *at one end*, so that the hammock is brought upright in the water. If the hammock itself and the ticking are pervious to the water, the water, aided by the increased pressure on the portion of the hammock a considerable distance below the surface, soon finds its way in, and gradually destroys the buoyancy by forcing the air out; a weight of *six* pounds of iron *so suspended* sank a hammock in five minutes.

The weight of the water displaced by the hammock was estimated at, ...	lbs. 138·24
The weight of the hammock, viz., bed and blanket, when dry..	24·5
Buoyancy of hammock at first	113·74 lbs.
	in.
The length of hammock	55·5
Diameter of ditto	9·25
Volume of hammock..	2·16 cubic feet.

If an equal weight, viz. 6 lb., were suspended at the *middle* of the hammock, the latter would float much longer. The result of further

experiments made by Captain Wilmshurst has been, that the ordinary hammock floating *horizontally*, will support 6 lbs. of iron for nine minutes. The effect of oiling the bed-cover, or ticking, was that the hammock floated the 6 lbs. weight for 2½ hours, and would, no doubt, have supported a man for nearly as long. It is hardly necessary for me to state that the buoyancy requisite to support a man in the water who remains quite self-possessed, does not exceed a few lbs.; but it would be well to aim at providing for each man a buoyancy of 20 lbs., and if the hammock is to support two men easily and continuously, then 40 lbs.

I have ascertained that the horsehair bed supplied to the seamen of the Royal Navy is charged to them at ten shillings and sixpence; that beds stuffed with cork shavings can be supplied wholesale (by the Messrs. Birt, who make the well-known Cork Life Belts for the Admiralty) at five shillings each, and that with cocoa-nut fibre they would cost rather more than five shillings, viz., about seven shillings and sixpence, and would not have so much buoyancy, but they might be more comfortable.

A mattress of the following dimensions, viz. 6 ft. × 4 ft. × 4 inches weighs 20 lbs. if stuffed with cork shavings. Its buoyancy, which in the case of cork shavings is four times its weight in pounds, is said to be 80 lbs., *i.e.*, it will support an iron weight of that amount. The mattrass on the table has a buoyancy of 26 lbs.

The valuable buoyancy that exists even in an ordinary naval hammock is, I think, established by the experiments above referred to. The increased buoyancy that can be given to it by various means, viz., by making the hammock or the tick impervious, or by substituting cocoanut fibre or cork shavings for horsehair have been pointed out, and the question may now, I think, be safely left in the hands of the Naval authorities, who have an opportunity of practising economy and promoting efficiency at the same time. The mattrass stuffed with cork shavings is less than half the cost of the hair mattress now supplied, viz., only five shillings. The reason why the cork shaving mattrasses are so cheap is that the shavings are refuse, and would otherwise be burnt.

I may add that I have been informed since these experiments were tried for me at Malta, that an officer of rank, who was in Her Majesty's ship "Bombay," when she was burnt off Monte Video, has stated that if it had occurred to them to stand by hammocks before the men jumped overboard, all hands might have been saved. It will be remembered that a considerable part of the ship's company, including nearly all the Marines, and a great many boys, were drowned alongside, while the boats were floating in safety, but deeply overladen with men, a short distance off. The boom-boats could not be hoisted out, as the falls were burnt, and there was not time to make a raft, all hands being employed until the last instant in vain attempts to put out the fire.

Captain T. E. Symonds, R.N.: As a supplement to Admiral Ryder's suggestion, I may mention that a gentleman, Mr. Herbert Hounsell, of Bridport, hearing that Admiral Ryder was about to read a paper on the subject of hammocks, has requested me to mention an invention, or an application, which he thought very good. It is to sub-

stitute for the canvas hammock, a netted one, adding a waterproof wrapper, which would be lashed up with the netted hammock in the same way that the ordinary hammock is lashed up. Added to the ordinary cork bedding, it would produce a body with more floating power than a canvas hammock, and impervious to wet. Unfortunately, this gentleman is not present to describe his views. It occurred to me at the time to be a valuable suggestion, and I thought the present a good opportunity to bring it forward. I may mention that, added to the advantage Admiral Ryder has described, the netted hammock is considerably cheaper than the ordinary canvas hammock, and it has the additional advantage of not requiring constant scrubbing.

Admiral RYDER: The reason why the cork shavings are at so low a price is, because they would be otherwise burnt.

The CHAIRMAN: I have great pleasure in thanking Admiral Ryder for his suggestion.

EDITORIAL NOTE

THE editorial note on page 588 of No. lxi of the Journal appended to Major Lynden Bell's paper on "The Movements, &c., of Light Infantry," was inadvertently inserted, his paper having been written on 29th June, 1870, whereas the Field Exercise book was not issued until 1st September of that year.—ED.

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